MODERN MECHANISM

EXHIBITING THE LATEST PROGRESS IN MACHINES, MOTORS, AND THE TRANSMISSION OF POWER

EDITED BY

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PREFACE.

Appletons' Dictionary of Engineering, published in 1851, was the first work in which were gathered, in cyclopedic form, descriptions of the products of American mechanical industry. It served the best purpose of such a publication, in that it crystallized existing knowledge into concrete shape, digested it, and so rendered it easily available to the busy mechanic and engineer. Thirty years afterward—so great had been the advances due to American invention in every department of the mechanic arts—it was found that, to bring the work abreast of the time, its complete reconstruction was necessary. As a result, appeared Appletons' Cyclopædia of Applied Mechanics, in which of the older publication nothing remained save the small proportion which was valuable in point of historical interest, or which dealt with subjects still instructtive when brought into contrast with later achievements.

No work of a technical character so signally and so quickly demonstrated its own usefulness. It became at once the recognized standard of American mechanical practice. It found its way into the workshops and the manufactories and the technical schools all over the land. It has borne a prominent part in the education of the American mechanic as he is to-day; and, more than any other literary production, it has helped him toward the pre-eminence which he has attained.

But modern progress in all the great fields of invention and discovery is moving with a constantly accelerating speed. In the bending of that great force of Nature which we call "electricity" to human needs, advances are becoming almost a matter of hours. A decade of such onward motion calls for a new record—a new crystallization of the results—and a new effort to bring them in the same tried and assimilable form to those who constitute "the hands of the nation." Hence the present volume.

It is not a revision. It is a new book, dealing solely with the principal and most useful advances of the past ten years; and it is therefore issued under a new name which exactly describes its contents—Modern Mechanism. It does not supersede the Cyclopædia of Mechanics, but adds to it.

A word, in conclusion, as to how the book has been made. Countless letters and circulars asking information on mechanical topics have been sent to manufacturers and engineers throughout the country. A large collection, not merely

of trade literature but of valuable practical suggestions, has thus been gathered; and this has been supplemented by the best papers which have appeared in American and foreign technical periodicals and in the transactions of engineering societies. The great mass of accumulated material, carefully digested, has been intrusted to eminent experts on each subject, and by them has been winnowed and selected in the light of their special knowledge and judgment. The result is now submitted to the higher adjudication of the master-mechanics of the United States.

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MODERN MECHANISM.

AËRIAL NAVIGATION. Within the last decade a balloon has been driven against a moderate wind, and a man is said to have flown a hundred yards near Paris. A number of skilled observers are investigating the elements of air resistances and reactions, and the law which governs flight. The problems of aërial navigation are passing into the hands of the engineers.

I. BALLOONS.—As regards balloons, it has been proved that an elongated gas-bag can be propelled through the air with a screw, and steered with a rudder; that it can be made stiff enough by internal gas pressure to resist the speeds hitherto attained, and that the velocity is limited by the power and weight of the motor, which the buoyancy of the balloon enables it to carry up. Thus far, as the outcome of various experiments, dating back to 1852—first by Giffard, the inventor of the injector, next (1872) by Dupuy de Lôme, the French chief naval constructor, and then (1883) by Tissandier, the distinguished author and aëronaut—in which constantly increasing velocities have been reached—a maximum speed of 14 miles an hour has been attained. This was accomplished by Commandant Renard, of the aëronautical establishment of the French War Department, who in 1884–'85 made seven trial trips, on five of which he was enabled to return to his point of departure.

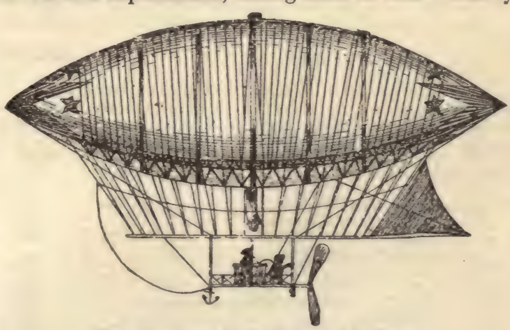


FIG. 1.—Tissandier's electrical balloon.

The Tissandier Electrical Balloon is represented in Fig. 1, and is 92 ft. long and 30 ft. in diameter (3·04 to 1), inflated with 37·439 cub. ft. of hydrogen, and has a lifting power of 2,728 lbs. The netting in this case was formed of flat ribbons sewed to longitudinal gores, which arrangement was found materially to diminish the air resistance due to the ordinary twine netting. The apparatus was driven by a Siemens dynamo weighing 99 lbs., actuated by a primary battery (bichromate of potash) weighing 517 lbs., and capable of developing 1½ horse-power for 2½ hours. The screw was 9·18 ft. in diameter, with two arms, and was rotated at 180 revolutions per minute. The apparatus, at a height of 1,600 ft., was just able, while exerting the full power of its motor, to stem a breeze blowing at the rate of 6·7 miles per hour. On a subsequent trial it is claimed by M. Tissandier to have made a speed of 9 miles per hour. On neither trial could the balloon return to its starting-point. The results were so far inferior to those obtained at about the same time by the French War Department that further experiments with this balloon were not prosecuted.

The French War Balloon.—The aëronautical establishment of the French War Department at Calais was reorganized in 1879. In 1884 the officers in charge, Messrs. Renard and Krebs, built an elongated balloon 165 ft. long by 27½ ft. in diameter, in which the largest section was no longer placed midway of the spindle, as in all previous attempts, but toward its front end, as obtains in the case of birds and fishes. Moreover, they placed the screw in front instead of behind, as previously practiced; but the great improvement consisted in largely increasing the energy of the motor in proportion to its weight. Besides this, they obtained stability and stiffness by the use of an internal air-bag and a better mode

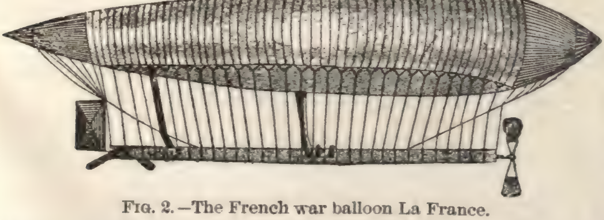


FIG. 2.—The French war balloon La France.

of suspension, and they inclosed the whole apparatus in a shed, so that it might be kept permanently inflated and await calm days for experiment. This air-ship, which was named La France, held 65,836 cub. ft. of hydrogen, and its lifting power was 4,402 lbs. The car was very long (105 ft.), in order to equalize the weight over the balloon and yet admit of both being placed close together, in order to bring the propelling arrangements as near the center line of gravity as possible. The screw was placed on the car: it had two arms, and was 23 ft. in diameter. The power of the motor was ascertained by experiment in the shop to amount to 9 horse-power, and speeds of 17 to 20 miles per hour were expected with 46 revolutions of the screw. Fig. 2 represents this air-ship. Experiments made with La France gave a speed of 14 miles per hour with an electric motor of 9 horse-power, weighing, with its primary battery, 1,174 lbs., this being the utmost that the air-ship could lift, in addition to its own weight and that of the aëronauts and their supplies. Further calculations show that by simply doubling the dimensions of the balloon its lifting power will be so much increased that a motor weighing at the same rate—130 lbs. per horse-power—will produce a speed of 25 miles per hour. This, however, depends upon the practicability of a balloon 330 ft. long—which remains to be proved. Commandant Renard, after stating that "the conquest of the air will be practically accomplished when a speed of 28 miles per hour is obtained," expresses the opinion that we are on the eve of freely navigating the air, and that probably France will possess the first aërial fleet. It is stated that the German, Russian, and Portuguese Governments have recently organized aëronautical establishments, and are experimenting in secret. Should some notable success follow, it will not be the first time that a great invention has been advanced by the necessities of war. Leaving speculation, however, the accompanying table gives the principal data as to the four air-ships which have been described, and the horse-power necessary to drive them at 25 miles per hour. The last line shows how light a motor must be to produce 25 miles per hour without increasing the weight.

Schedule of Navigable Balloons.

DATA.	Giffard, 1852.	Dupuy de Lôme, 1872.	Tissandier, 1883.	Renard and Krebs, 1884–'85.
Length, out to out....ft.	144·3	118·47	91·84	165·21
Diameter, largest section.... "	39·3	48·67	30·17	27·55
Length to diameter....proportion	3·67 to 1	2·43	3·04	6
Cubic contents....ft.	88,300	120,088	37,439	65,836
Ascending power....lbs.	3,978	8,358	2,728	4,402
Weight—Balloon and valves....lbs.	704	1,255·5	374	812
" Netting and bands.... "	330	396	154	279
" Spars and adjuncts.... "	660	1,316·5	75	170
" Rudder and screw.... "	....	165	....	193
" Anchor and guide-rope.... "	176	308	110	.....
" Car complete.... "	924	1,287	220	995
" Motor in working order.... "	462	2,000	616	1,174
" Aëronauts.... "	154	310	330	308
" Ballast and supplies.... "	567·6	1,320	849	471
" Total apparatus....lbs.	3,977·6	8,358	2,728	4,402
Horse-power of motor....	3	0·8	1·5	9
Weight of motor per horse-power....lbs.	154	2,500	410	130
Speed obtained....miles per hour	6·71	6·26	6·71	14
Horse-power required 25 miles per hour....	155	52 (?)	77	51
Motor lbs. per horse-power....	3	38 (?)	8	23

Possible Improvements in Balloons.—The greatest speed thus far attained has been 14 miles per hour, which is insufficient to cope with most of prevailing winds, particularly at sailing heights above the ground, and the following difficulties have been encountered and to a certain extent overcome:

1. Excessive loss of gas in early experiments. This has been remedied by closer tissue of envelope and better varnishes, as well as by regulating valves, so that the loss of gas has been reduced so as to average less than 2 per cent per day.

2. Resistance of air to forward motion. This has been largely diminished by pointed ends, but much remains to be done in ascertaining the best proportions.

3. Need of a propeller to act on the air. This has been measurably solved by the aërial screw, which is said to exert from 50 to 70 per cent. of the power applied, but is yet less efficient than the marine screw, which works up to 84 per cent.

4. Need of steering gear. This has been fairly worked out by various arrangements of rudders and keel cloths, which have given command of the apparatus when in motion.

5. Need of a light motor. This is the great difficulty. Steam has been tried with a weight of 154 lbs. per horse-power, including fuel and water, and electric engines with a weight of 130 lbs. per horse-power. Neither are sufficiently light to give the necessary speed, except for very large apparatus.

6. Need of endwise stiffness. This has been remedied by compressing the gas inside the balloon, either through the use of a loaded safety-valve or through the use of an internal air-bag. As speed increases more will needs be done in this direction, and this will require stronger and heavier envelopes for the gas-bag.

7. Need to prevent deviations in course. This has been overcome by placing the screw in front, where it is more effective than behind.

8. Need of longitudinal stability. This has only been partly solved by various methods of suspension. There is still a tendency to pitch when meeting gusts of air, and this will increase when greater speeds are attained. It will need to be worked out by experiment.

9. Need of altitudinal stability. This is the tendency of the balloon to rise or fall with the heating or cooling of the gas. It has been met in only a crude way by alternately discharging either gas, to prevent the balloon from bursting, or ballast, to prevent it from coming down. This rapidly exhausts both gas and ballast, and limits the time of the trip. It has been repeatedly proposed to substitute for this method a vertical screw, to raise and depress the balloon, which should then be at starting slightly heavier than the air which it displaces. The great desideratum is to gain increased speed, and there are at least four ways by which this may be accomplished: 1. By giving the balloon a better form of hull, so as to diminish the resistance. La France was rather blunt in front, and there is reason to believe that by simply moving the largest section farther back, increased speed will result. 2. By designing a more efficient aërial screw. Commandant Renard has been experimenting in this direction, and says there is a shape much better than others, and that this form can not be departed from without getting very bad screws; falling, as he expresses it, into a veritable precipice on either side. 3. By devising a lighter motor, in proportion to its energy. This is the great field in which work remains to be done. 4. By simply building larger air-ships, for, inasmuch as their contents, and consequent lifting power, will increase as the cube of their dimensions, while their weight will, approximately, only increase as the square, the surplus lifting power will evidently increase with the size, and greater motive power in proportion can be used.

Let us suppose, for the sake of this argument, that no improvement whatever has been achieved in either of the first three ways which have been mentioned, and inquire simply what would be the effect of doubling the dimensions of La France. The comparison will be approximately as follows:

PRINCIPAL DIMENSIONS.	La France.	Double size.
Length, out to out ....ft.	165	330
Diameter, largest section .... "	27·5	55
Contents of gas ....cub. ft.	65,836	526,688
Lifting power ....lbs.	4,402	35,216
Weight of apparatus .... "	2,451	9,804
" cargo and aëronauts .... "	779	1,500
" machinery .... "	1,174	23,912

From the data obtained by his experiments, M. Renard has deduced the following formulæ: (1) $R = 0{\cdot}01685D^2V^2$, (2) $W = 0{\cdot}016585D^2V^3$, and (3) $T = 0{\cdot}0326D^2V^3$; in which R is the air resistance to motion in kilogrammes; V, speed in metres per second; D, diameter of the balloon; W, work done in kilogrammetres; and T, work done on the shaft of the screw. From this he calculates that a balloon 32·8 ft. in diameter would require 43½ horse-power to drive it at 22 miles per hour.

As the motor (dynamo and battery) of La France weighed 130 lbs. per horse-power, we have for that of double the size $\frac{23912}{130} = 182$ horse-power motor, and calculating the speed by the formula of Commandant Renard, and inserting the new diameter, 16·8 metres, we have: $T = 0{\cdot}0326 \times \overline{16{\cdot}8^2} \times V^3$ in kilogrammetres.

But as we have 182 horse-power, and there are 75 kilogrammetres in the horse-power, we have further: $182 \times 75 = 0{\cdot}0326 \times \overline{16{\cdot}8^2} \times V^3$, whence $V = \sqrt[3]{\frac{13650}{9{\cdot}2}} = 11.2$ metres. So that we see that the speed of the new air-ship will be 11·20 metres, or 36·7 ft. per second—say, 25 miles per hour. The same result is arrived at by considering that the new balloon will require four times the motive power of La France to go at the *same speed*, and that the power required increases as the cube of the speed. So that we see that a speed of 25 miles per hour is even now in sight, without any other improvement than doubling the size of the balloon. It is evident, however, that somewhere a limit will be reached beyond which unmanageable sizes will be met with. The weight, the size, the resistance will increase, as well as the speed, and somewhere there will be impracticability. We have seen that to go 25 miles per hour, and thus brave the wind about three quarters of the time, we need an elongated balloon similar in shape to La France, 330 ft. long and 55 ft. in diameter. It is probable that, by improvement in the first three ways which have been mentioned, it may attain a speed of 30 or 35 miles per hour; but when it is attempted to obtain 40 miles per hour out of it, it will grow to lengths of, say, 1,000 ft., or as long as four ordinary city blocks, and diameters of 150 ft., or the height of an ordinary church steeple.

These seem unmanageable and impracticable sizes for ordinary uses. They are greater than those of ocean steamers, because the speed required is greater to overcome the aërial currents; and the care and maintenance of these great air-ships will be a difficult matter. It seems likely, therefore, that in the near future elongated balloons will be built which will be driven at 25 or 30 or a few more miles per hour, which will be able to sail about on all but

stormy days; but the cargoes carried in proportion to the size will be small, and to obtain speeds similar to those of express trains some other form of apparatus will have to be sought for.

War Balloons in the Field.—The ingenious appliances which were used by Italy during the recent Abyssinian War are illustrated in Figs. 3, 4, and 5. Abyssinia is not a country in which the gas necessary for the inflation of balloons can be easily procured. It was necessary to provide an apparatus for the production of the gas, and to find a fit means of transporting it across the desert. Fig. 3 represents a balloon ascent in the field. The inflation has just been effected, and the balloon, held by a rope attached to a windlass, is swaying in the air. In countries provided with gas-works, the inflating is usually effected by means of illuminating gas, and it is only necessary to connect the balloon with one of the city mains. In the case under consideration, the gas, produced by a process hereafter explained, was contained in forty tubes, united in two groups of twenty, with a barrel that supplied the conduit, which ends at the place where the balloon is located in the center of a circle of ballast-bags. Around the drum of the windlass winds the cable, the extremity of which is affixed to a trapeze that surrounds the car. Within the cable, which is of several strands, there are two telephone wires, which are not exactly in the center, but a little to one side, in order that, in case of a breakage, the point where the accident occurred may be known at once. By this means the balloon is constantly in communication with those who remain below, who can instantaneously pay out or draw in the cable at will. It takes ten men to do the manœuvring, the traction to be exerted not exceeding 650 lbs. in a pretty swift wind, and but 325 lbs. in a dead calm. These balloons are wholly of silk, and are so pliable that each fits into its car, which has a capacity of but 35 cub. ft. The whole is contained in a compartment in the hind carriage of the vehicle (Fig. 4), the front part of which is occupied by the windlass. The carriage is very low, and is built to withstand shocks and jolting. It requires but two horses to draw it, since the whole weighs but about 1,425 lbs. The hydrogen is prepared in a special apparatus, represented in Fig. 5. This apparatus, which is quite cumbersome, can not be carried everywhere, and so, in certain cases, the gas must be carried all prepared. In order to reduce its volume, the idea has occurred to compress it under very great pressure into very strong steel cylinders. Each of these latter weighs 65 lbs., and is 8 ft. in length, 5 in. in diameter, and ½ in. in thickness. The gas is preserved therein, without any loss, at a pressure of 135 atmospheres. It takes from 70 to 75 of these cylinders to inflate a balloon of 10,500 cub. ft. They are borne upon another carriage, and, as their total weight is between 4,400 and 5,000 lbs., they can be easily hauled by three horses. In Abyssinia, when the land did not allow of the passage of a vehicle, these cylinders were carried upon the backs of camels. In the operation of inflating, but one cyl-

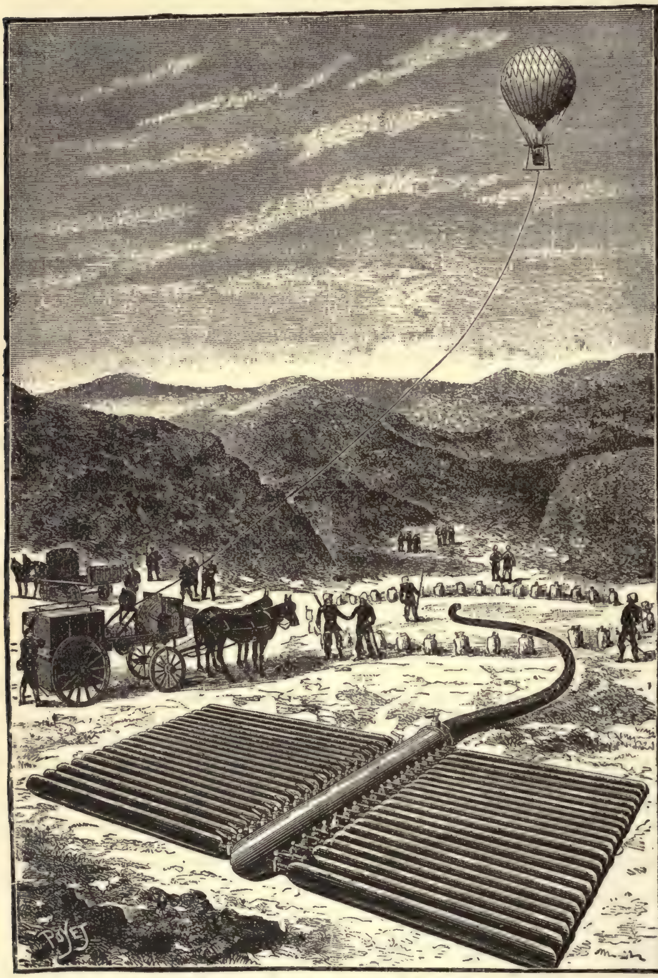


Fig. 3.—Balloon operations in Abyssinia.

inder is opened at a time, since the gas, in passing from 135 atmospheres to 1 atmosphere, would produce through its expansion an intense cold, and so, in order not to cool it, it is

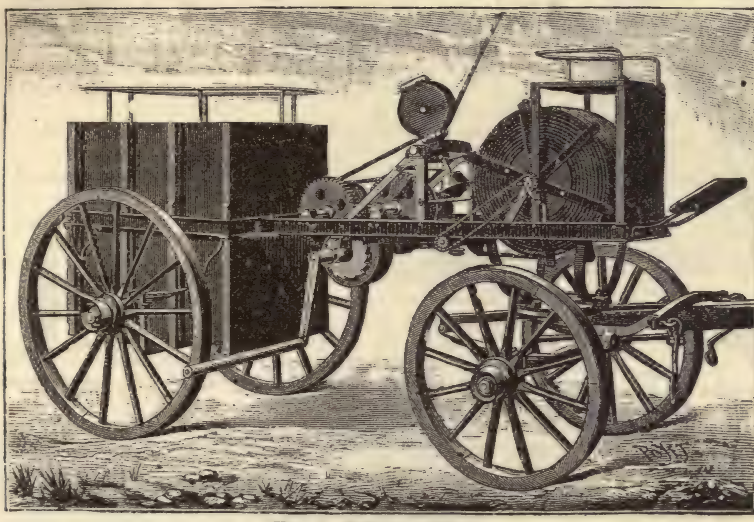


Fig. 4.—Balloon carriage.

necessary to operate successively cylinder by cylinder. In the manufacture of the hydrogen gas in the apparatus represented in Fig. 5, iron filings immersed in dilute acid are placed in two large generators. The gas formed by the decomposition of the iron escapes through a pipe fitted to each generator, and passes into a large vessel filled with water, and called a purifier, where it is freed from all its impurities. It then ascends in a conduit, whence it makes its exit ready for use, and to be stored in the steel cylinders. This gas-generator, which is very simple, can be easily transported to the vicinity of the field of operations of an army.

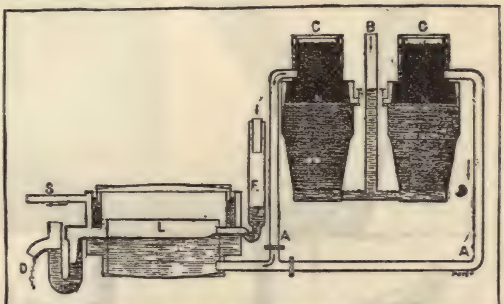


Fig. 5.—Charging apparatus for war balloons.

II. Flying - Machines.—These are usually constructed upon one or the other of the following principles: 1. The imitation of the flapping action of the wings of birds. 2. The sustaining of weight and obtaining progress simultaneously through the air by horizontal screws. 3. The sustaining of weight by fixed aëroplanes, and the obtaining progress by means of screws. A great many experiments have been tried and a great deal of ingenuity has been expended in each of these three directions, but thus far not a machine has been able to leave the ground with its prime motor, and what measure of success has been attained can only be exhibited through toys, which give an idea of the principles involved.

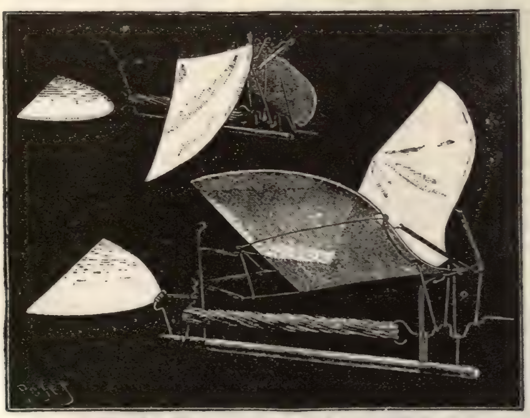


Fig. 6.—Pichancourt's mechanical bird.

Pichancourt's Mechanical Bird, represented in Fig. 6, is about 12 in. from tip to tip of wings, and weighs 385 grs., one third of which consists in the twisted rubber strings furnishing the motive power. The necessary flexion of the wings, to obtain a propelling as well as a sustaining reaction, is produced by triple eccentrics, each actuating a lever fastened to a different point in the wings. Upon being wound up and released, the apparatus flies slightly upward, and to a distance of 30 to 60 ft. in from 3 to 6 seconds. Similar

but larger birds, of the same make, are said to have flown up to a height of 25 ft. and a distance of 70 ft. against a slightly adverse wind. The relative power absorbed, however, is quite beyond the capacity of any known prime motor.

Dandrieux's Artificial Butterfly (Fig. 7) is an example of an aërial screw used to sustain and to propel simultaneously by its horizontal revolutions. It has been proved, however, that about 1 horse-power of energy is required to sustain 33 lbs. in the air. Fig. 8 represents a similar contrivance propelled by two screws. The motive power in both devices is furnished by a twisted rubber cord.

FIG. 7.—Dandrieux's butterfly.

Hargrave's Flying-Machines.—Mr. Laurence Hargrave, of Sydney, New South Wales, has been experimenting for many years with models of flying-machines, and has succeeded in getting longer flights than any hitherto obtained. Up to December 3, 1890, he had constructed nine aëroplanes, operated by bands of India-rubber and propelled by wings; one operated by rubber bands and a screw; two operated by compressed air, with wings; and two operated by means of a cross-bow, with wings. From Mr. Hargrave's experiments he concludes that the wing and the screw are about equally efficient in action. His first screw-propelled aëroplane weighed 2 lbs. and was driven by the contractile power of 48 elastic bands, geared in tension, a horizontal distance of 120 ft., by the expenditure of 196 foot-pounds. Another machine in which flapping wings were similarly driven, weighed 33¼ oz. and flew a distance of 270 ft. with 470 foot-pounds of energy. In 1890 he constructed the compressed-air flying-machine, shown in Fig. 9. The body of the machine consists of a tube 2 in. in diameter and 48¼ in. long, weighing 19½ oz., and with a capacity of 144·6 cub. in. It holds the compressed air at a working pressure of 230 lbs. to the sq. in. The engine cylinder is 1½ in. diameter and 1¼ in. stroke, the total weight of the compressed-air engine being 6½ oz. The area of the aëroplane measures 2,128 sq. in., and that of the wings is 216 sq. in., thus giving a total area of 2,344 sq. in. for a total weight of 2·53 lbs. The wings are made of paper, and have no feathering motion, save that due to the elasticity of the material of which they are composed. In a dead calm the machine flew 368 ft. horizontally, with an expenditure of 870 foot-pounds of energy. The engraving shows also two forms of air-compressing pumps. (See *Engineering*, December 26, 1890; also *Journal of the Royal Society of New South Wales*, vol. xxiv.)

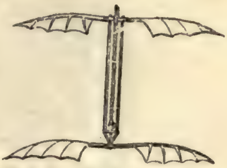


FIG. 8.—Mechanical bird.

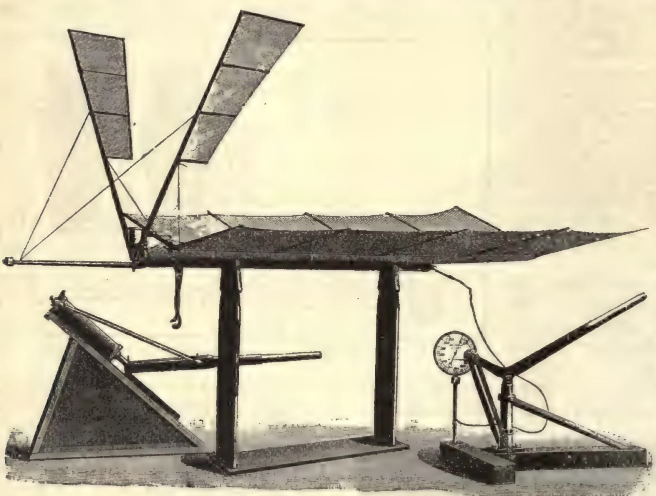


FIG. 9.—Hargrave's flying-machine.

Trouvé's Mechanical Bird, devised by M. Gustave Trouvé, Fig. 10, is claimed by its inventor to be the first machine which has risen into the air by its own unaided force. The bird consists of two wings, *A* and *B*, connected by a "Bourdon" bent tube, such as is used in steam-gauges, the peculiarity of which is that when pressure increases within the tube its outer ends move apart, and return toward each other upon diminished pressure. M. Trouvé increases the efficiency of this action by putting a second tube within the first, and he produces therein a series of alternate compressions and expansions, by exploding twelve cartridges contained in the revolver-barrel, *D*, which communicates with the "Bourdon" tube. These explosions produce a series of strokes of the wings, which, with the aid of the silk sustaining-plane, indicated at *C*, both support and propel the bird in the air. The manner of starting it is represented in Fig. 11. The bird is suspended from a frame by a thread attached to the hammer of the revolver, thus keeping it up from the cap. Another thread holds the bird near the upright post, while a common candle, *A*, and a blow-pipe flame, *B*, complete the preparations. Upon the thread being burned at *A*, the bird swings forward from position *1* to position *2*, when, the other thread being burned by the flame, the

hammer falls on the cap, an explosion ensues, the tube expands, and the wings strike downward, while the bird flies up, as shown in position *3*. Then the gases escape from the tube, the latter resumes its original shape, thus raising the wings and also moving a pawl, which advances the revolver-barrel, so that a new explosion occurs, and so on. The bird has flown 80 yards.

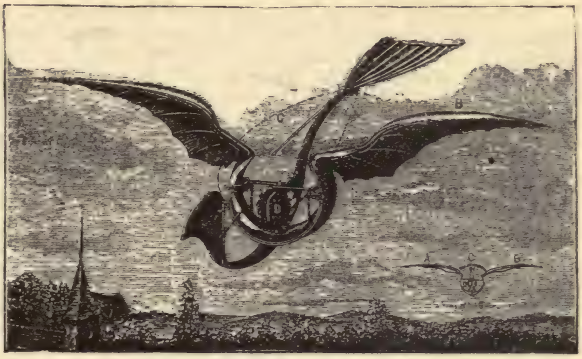


Fig. 10.—Trouvé's mechanical bird.

Goupil's Aëroplane, represented in Fig. 12, was constructed in 1883. It measures about 20 ft. across, 26 ft. from back to rear end, 290 sq. ft. in supporting area, and weighs 110 lbs. Placed in a wind varying from 16 to 20 ft. per second, at an angle of incidence of 10°, it lifted up two men in addition to its own weight, making a total of 440 lbs. When the wind velocity increased to over 20 ft. per second, the apparatus became unmanageable.

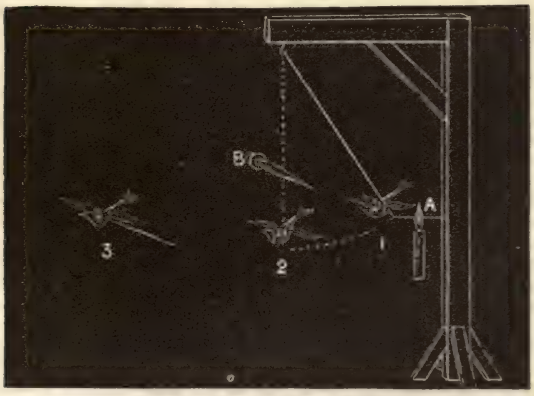


Fig. 11.—Starting Trouvé's bird.

Ader's Flying-Machine resembles a huge bat. The details of the apparatus are kept secret. The motor, however, actuates a screw of sail-cloth, which is placed at the head of the apparatus in order to pull instead of to push it. The machine rests upon sled runners, on which it is caused to slide for some 20 or 30 yards in order to be started. M. Mouillard, of Cairo, has devised an apparatus which consists simply in a light aëroplane strapped to the body and resting on the shoulders, but, unfortunately, only slightly adjustable to conform to the various conditions of flight. The wind was almost *nil,* and in order to test the carrying capacity of his aëroplane he took a running jump across a 10-ft. ditch, when, a light breeze springing up, he was actually picked up and sailed against the wind for 138 ft., his legs dangling down within a foot of the ground, without being able to alight.

Experimental Researches on Mechanical Flight.—Prof. S. P. Langley has made a series of investigations which show that, with motors having the same weights as those actually constructed, we possess at present the necessary force for sustaining, with very rapid motion, heavy bodies in the air; for example, inclined planes more than a thousand times denser than the medium in which they move. Further, from the point of view of these experiments and also of the theory underlying them, it appears to be demonstrated that if, in an aërial movement we, have a plane of determined dimensions and weight, inclined at such angles and moving with such velocities that it is always exactly sustained in horizontal flight, the more the velocity is augmented, the greater is the force necessary to diminish the sustaining power. It follows that there will be increasing economy of force for each augmentation of velocity, up to a certain limit which the experiments have not yet determined.

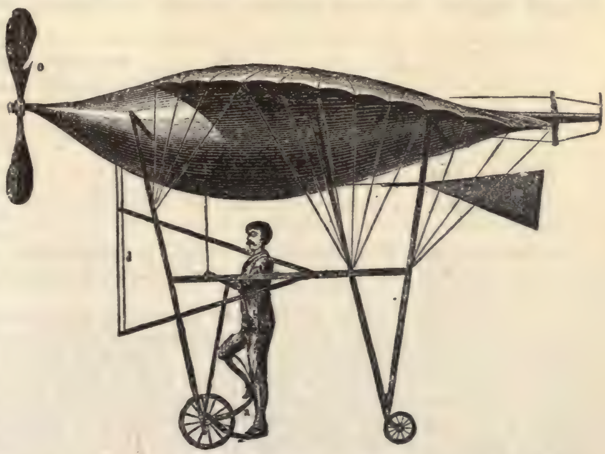


Fig. 12.—Goupil's aëroplane.

Prof. Langley says, in his memoir to the French Academy of Sciences, July 13, 1891: "The experiments which I have made during the last four years have been executed with an apparatus having revolving arms about 20 metres in diameter, put in movement by a 10 horse-power steam-engine. They are chiefly as follows: 1. To compare the movements of planes or systems of planes, the weights, surface, form, and variable arrangements, the whole being always in a horizontal position, but disposed in such a manner that it could fall freely. 2. To determine the work necessary to move such planes or systems of planes, when they are inclined, and possess velocities sufficient for them to be sustained by the reaction of the air in all the conditions of free horizontal flight. 3. To examine the motions of aërostats provided with their own motors, and various other analogous questions that I shall not mention here. As a specific example of the first category of experiments which have been carried out, let us take a horizontal plane, loaded (by its own weight) with 464 grammes, having a length 0·914 metre, a width 0·102 metre, a thickness 2 mm., and a density about 1,900 times greater than that of the surrounding air, acted on in the direction of its length by a horizontal force, but able to fall freely. The first line below gives the horizontal velocities in metres per second; the second. the time that the body took to fall in air from a constant height of 1·22 metres, the time of fall in a vacuum being 0·50 second:

"Horizontal velocities......................0 m., 5 m., 10 m., 15 m., 20 m.
Time taken to fall from a constant height
of 1·22 metres.........................0·53 s., 0·61 s., 0·75 s., 1·05 s., 2·00 s.

"When the experiment is made under the best conditions, it is striking, because, the plane having no inclination, there is no vertical component of apparent pressure to prolong the time of fall; and yet, although the specific gravity is in this more than 1,900 times that of the air, and although the body is quite free to fall, it descends very slowly, as if its weight were diminished a great number of times. What is more, the increase in the time of fall is even greater than the acceleration of the lateral movement. The same plane, under the same conditions, except that it was moved in the direction of its length, gave analogous but much more marked results; and some observations of the same kind have been made in numerous experiments with other planes, and under more varied conditions. From that which precedes, the general conclusion may be deduced that the time of fall of a given body in air, whatever may be its weight, may be indefinitely prolonged by lateral motion, and this result indicates the account that ought to be taken of the inertia of air in aërial locomotion, a property which, if it has not been neglected in this case, has certainly not received up to the present the attention that is due to it. By this (and also in consequence of that which follows), we have established the necessity of examining more attentively the practical possibility of an art very admissible in theory—that of causing heavy and conveniently disposed bodies to slide or, if I may say so, to travel in air. In order to indicate by another specific example the nature of the data obtained in the second category of my experiments, I will cite the results found with the same plane, but carrying a weight of 500 grammes—that is 5,380 grammes per square metre, inclined at different angles, and moving in the direction of its length. It is entirely free to rise under the pressure of the air, as in the first example it was free to fall; but when it has left its support, the velocity is regulated in such a manner that it will always be subjected to a horizontal motion.

"The first column of the following table gives the angle (a) with the horizon; the second the corresponding velocity (V) of *planement*—that is, the velocity which is exactly sufficient to sustain the plane in horizontal movement, when the reaction of the air causes it to rise from its support; the third column indicates in grammes the resistances to the movement forward for the corresponding velocities—a resistance that is shown by a dynamometer. These three columns only contain the data of the same experiment. The fourth column shows the product of the values indicated in the second and third—that is to say, the work T, in kilogrammetres per second, which has overcome the resistance. Finally, the fifth column, P, designates the weight in kilogrammes of a system of such planes that a 1 horse-power engine ought to cause to advance horizontally with the velocity V, and at the angle of inclination a.

	V	R	$T = \frac{VR}{1000}$	$P = \frac{500 \times 4554}{T \times 60 \times 1000}$
45	11·2	500	5·6	6·8
30	10·6	275	2·9	13·0
15	11·2	128	1·4	26·5
10	12·4	88	1·1	34·8
5	15·2	45	0·7	55·5
2	20·0	20	0·4	95·0

"As to the values given in the last column, it is necessary to add that my experiments demonstrate that, in rapid flight, one may suppose such planes to have very small interstices, without diminishing sensibly the power of support of any of them. It is also necessary to remark that the considerable weights given here to the planes have only the object of facilitating the quantitative experiments. I have found that surfaces approximately plane, and weighing ten times less, are sufficiently strong to be employed in flight, such as has been actually obtained, so that in the last case more than 85 kilogrammes are disposable for motors and other accessories. As a matter of fact, complete motors weighing less than five kilogrammes per horse-power have recently been constructed. Although I have made use of planes for my quantitative experiments, I do not regard this form of surface as that which gives the best results. I think, therefore, that the weights I have given in the last column

may be considered as less than those that could be transported with the corresponding velocities, if in free flight one is able to guide the movement in such a manner as to assure horizontal locomotion—an essential condition to the economical employment of the power at our disposal. The execution of these conditions, as of those that impose the practical necessity of ascending and descending with safety, belongs more to the art of which I have spoken than to my subject.

"The points that I have endeavored to demonstrate in the memoir in question are: 1. That the force requisite to sustain inclined planes in horizontal aërial locomotion diminishes, instead of increasing, when the velocity is augmented; and that up to very high velocities—a proposition the complete experimental demonstration of which will be given in my memoir; but I hope that its apparent improbability will be diminished by the examination of the preceding examples. 2. That the work necessary to sustain in high velocity the weights of an apparatus composed of planes and a motor may be produced by motors so light as those that have actually been constructed, provided that care is taken to conveniently direct the apparatus in free flight; with other conclusions of an analogous character."

Mr. Hiram S. Maxim publishes in *The Century Magazine*, October, 1891, a paper on aërial navigation, detailing his experiments as to the power required. Commenting on Prof. Langley's statement that with a flying-machine the greater the speed the less would be the power required, he says: "In navigating the air we may reason as follows: if we make no allowance for skin friction and the resistance of the wires and framework passing through the air—these factors being very small indeed at moderate speeds as compared to the resistance offered by the aëroplane—we may assume that with a plane set at an angle of 1 in 10, and with the whole apparatus weighing 4,000 lbs., the push of the screw would have to be 400 lbs. Suppose now that the speed should be 30 miles an hour; the energy required from the engine in useful effect on the machine would be 32 horse-power (30 miles = 2,640 feet per minute. $\frac{2640 \times 400}{33000} = 32$). Adding 20 per cent for slip of screw, it would be 38·4 horse-power. Suppose now that we should increase the speed of the machine to 60 miles an hour, we could reduce the angle of the plane to 1 in 40 instead of 1 in 10, because the lifting power of a plane has been found to increase in proportion to the square of its velocity. A plane traveling through the air at the rate of 60 miles an hour, placed at an angle of 1 in 40, will lift the same as when placed at 1 in 10, and traveling at half this speed. The push of the screw would therefore have to be only 100 lbs., and it would require 16 horse-power in useful effect to drive the plane. Adding 10 per cent for the slip of the screw, instead of 20, as for the lower speed, would increase the engine-power required to 17·6 horse-power. These figures of course make no allowance for any loss by atmospheric friction. Suppose 10 per cent to be consumed in atmospheric resistance when the complete machine was moving 30 miles an hour, it would then require 42·2 horse-power to drive it. Therefore, at 30 miles an hour only 3·84 horse-power would be consumed by atmospheric friction, while with a speed of 60 miles an hour the engine-power required to overcome this resistance would increase eight-fold, or 30·7 horse-power, which, added to 17·6, would make 48·1 horse-power for 60 miles an hour.

"It would therefore stand as follows:

For 30 Miles per Hour.

Power required to overcome angle of plane	32
Power required to compensate for loss in slip of screw	6·4
Power required to overcome atmospheric friction	3·84
Total horse-power	42·24

For 60 Miles per Hour.

Power required to overcome angle of plane	16
Power required to compensate for loss in slip of screw	4
Power required to overcome atmospheric friction	30·7
Total horse-power	50·7

"If, however, the element of friction could be completely removed, the higher the speed the less would be the power required. My experiments go to show that certainly as much as 133 lbs. can be carried with the expenditure of 1 horse-power, and under certain conditions as much as 250 lbs. Some writers who have based their calculations altogether on mathematical formulæ are of the opinion that as much as 500 lbs. can be carried with 1 horse-power. From the foregoing it would appear that if a machine with its motor complete can be made to generate 1 horse-power for every 100 lbs., a machine might be made which would successfully navigate the air. After studying the question of motors for a good many years, and after having tried many experiments, I have come to the conclusion that the greatest amount of force with the minimum amount of weight can be obtained from a high-pressure compound steam-engine using steam at a pressure of from 200 to 350 lbs. to the square inch, and lately I have constructed two such engines, each weighing 300 lbs."

The whole subject of aërial navigation has been very fully and ably discussed by Mr. O. Chanute, C. E., from whose lecture, delivered before the students of Sibley College, Cornell University, the foregoing contains many abstracts. Se also a series of articles by Mr. Chanute in *The New York Railroad and Engineering Journal*, 1891; also recent files of the French scientific weekly, *La Nature*.

Aërostat: see Aërial Navigation.

AGRICULTURAL MACHINERY. Machinery for agricultural purposes consists in: 1. Implements for clearing land and for ditching. 2. Implements for preparing land for the reception of seed. 3. Implements for planting the seed. 4. Implements for the cultivation of the growing plants. 5. Implements for harvesting crops. 6. Implements for preparing the crops for use. 7. Implements for miscellaneous agricultural purposes.

This classification conforms to the course of the farm history of the crop.

For information relating to farm appliances associated directly with tillage and crops see CULTIVATORS; COTTON-GIN; CARRIAGES AND WAGONS; CREAMERS; DITCHING MACHINES; ELEVATORS; ENSILAGE MACHINES; HAY CARRIER; HAY LOADER; HAY-RAKE; HORSE-POWER; HARVESTING MACHINERY; GRAIN HARVESTER; COTTON LOGGER; STEAM MILLING-MACHINES; GRAIN-MOWERS; PLOWS; POTATO-DIGGER; PRESSES, HAY AND COTTON; PULVERIZERS AND HARROWS; REAPERS; SEEDERS AND DRILLS; SHEEP-SHEARING MACHINE; STALK CUTTERS; STUMP PULLERS; THRESHING MACHINE; WATER WHEELS.

In general, late tendencies are toward the substitution of metals for wood, and of rolled and malleable irons and rolled steel in place of cast-iron parts in agricultural-machine structure—a growing change especially noticeable in plows, harrows, seeders, harvest-machines, and apparatus for handling the hay crop. This movement directs the effort of iron and steel workers to supplying the machine factories with the special forms possessing the qualities specifically required. It arises partly from a sensible natural limit to available supplies of suitable hard woods in necessary lengths, and partly from a preference among farmers for metallic machines, especially in those types which are subject to locomotion while working, as the joints can be made permanently firmer under the racking strains of movement over rough farm-land. It has stimulated the introduction of new processes in the great iron and steel works for cold-rolling special forms, and for producing cast steel in forms convenient to cut up into the shapes for making the tools and dies used in the agricultural-machine factories. Piping is also largely supplied for the framework of some of the harvest-machines. Brass, aluminum-bronze, babbitt, and other composite-metal low-friction bearings are supplied for the better grades of machines. Steel plates are rolled into rims for the light strong support-wheels, with any requisite ribs, nuptions, or other deviations rolled in to save factory work. The steel spokes of machine wheels are rolled, tapering, with elliptic section, in pairs butt to butt, and then sawed in two, for single spokes. Steel plates, formerly hand-hammered, are rolled to ultimate shape for use. Steel plowshares are cast in a "chill"—that is, a piece of cold metal of proper form is so introduced in the sand mold for the casting that the part or parts of the casting which are to be hardened come in contact with it when poured and instantly set, forming a hard skin of about $\frac{1}{16}$ in. in thickness on the softer and tough interior of the casting. Tempered wire required for the machines is, by a recent invention, automatically tempered to a reliable uniformity during the process of drawing. Wheel rims and tires are welded instantaneously by the heat of an electric current. Cut nails are superseded largely in machines by the new wire nails, round and of even diameter throughout the shank, cheaper in production, tougher in fiber, more tenacious in the wood, and of lighter weight than cut nails of like length. By what is known as "the Fitchburg process" of rolling metals, extraordinary shapes are rolled out in one operation, very cheaply where considerable quantities of a given shape are needed. Spiral springs in great variety and cold-pressed nuts with the hole in are cheaply produced in high perfection. Reaper cutter-bars, harvester frame-pieces, and plow-beams, formerly forged out by hand, are rolled from the steel, trimmed with heavy boiler-iron shears, and when straightened in the hydraulic press are ready for use. The work formerly done expensively and slowly upon them by the milling-machine is now rapidly and cheaply accomplished by the means mentioned and with satisfaction in results obtained. Largely owing to these improvements, introduced during the last decade (1881–1890), the farmer buys machines affected by them for from 25 to 50 per cent lower price than ten years ago. Another noticeable tendency is also seen toward complete automatic operation, with consequent economy of expenditure of skill, time, and money. The farmers of English-speaking countries, where this class of invention is rife, are adapting themselves with facility to the new methods of farming by machinery. Improved appliances in the hands of a large portion of the farming community force others to employ like facilities in competition. Their use is steadily tending to become compulsory, not only in enterprising but in all other industrial regions of the world, under penalty of famine and kindred calamity—for the important and essential effect is not really so much "labor-saving" as food-saving.

Air Blast: see Furnaces, Blast. **Air, Compressed, Air Drill**: see Coal-mining Machines. **Air Engine**: see Engines, Air. **Air Gun**: see Gun, Pneumatic. **Air Hammer**: see Hammers. Power. **Air Ship**: see Aërial Navigation. **Air Torpedo**: see Torpedo.

AIR, COMPRESSED, UTILIZATION OF. *Air-compressed Power Supply.*—The distribution of power by means of compressed air carried in pipes from a central station to several distant points of application has been chiefly adopted in mining and tunneling, for which purposes it has manifest advantages over all other systems of transmission. It has also been introduced to some extent as a means of supplying power to small consumers in cities, as in Birmingham, England, and in Paris. The largest installation of the kind, the one in Paris, is described in the *Proceedings of the Institute of Mechanical Engineers*, July, 1889, from which we extract the following: "The works of the Compagnie Parisienne de l'Air Comprimé, started in 1881 by M. Victor Popp, and situated in Rue St. Fargeau, Paris, distribute through some 40 miles of mains compressed air at a pressure of 90 lbs. per sq. in.,

which is utilized to the extent of nearly 3,000 horse-power. The special object in the first instance was to establish and maintain a system of pneumatic clocks in the streets, and for this purpose mains have been laid over a considerable portion of Paris. The means employed for working the large number of clocks now in use are very simple; they comprise a central station, the necessary mains and service-pipes, and the clock-dials with the special mechanism employed. At the central station a clock giving standard time actuates, at intervals of a minute, a valve connected with the reservoir of compressed air; during the first 20 seconds of each minute the valve allows the air to pass from the reservoir into the mains, and during the succeeding 20 seconds it permits the air to escape from the mains into the atmosphere. The mains consist of circuits of pipes laid from the central station, and connected together at frequent intervals, in order to multiply the means of supplying any given point. The pipes are of iron or lead, varying in diameter from 1·06 to 0·39 in., and are fitted at short intervals with three-way valves, accessible from the street surface, in order to divide the system into small sections without interfering with the service; the small service-pipes leading from the main into the houses are of lead, and vary from 0·39 to 0·16 in. diameter. The special device attached to each clock consists of a–small air-receiver or bellows, which by its successive dilatations and contractions imparts a regular movement to a small connecting rod carrying at one end a paul that works into a wheel cut with 60 teeth, and fixed to the minute-hand; a second paul prevents the backward movement of the wheel. The hour-hand is driven by a train of ordinary gearing. Some of these clocks are fitted with a bell for striking the hours, the mechanism being wound up gradually by each stroke of the bellows. The controlling clock at each station thus acts as the heart of the system, of which the station is the center, opening and closing at regular intervals the valve whereby air impulses are transmitted through the pipes to the various points of service. At the St. Fargeau works are two horizontal steam-engines of Corliss type, made by Messrs. Farcot, of St. Ouen, each of 60 horse-power, either of which is capable of supplying the compressed air necessary for working the pneumatic clocks in Paris, while the other stands in reserve. The actual power at present required for this purpose at the works is 35 horse-power, which is distributed through 40 miles of mains to 4,000 houses in the first and second arrondissements of Paris, and works about 9,000 clocks. As soon as it was found that the power produced was in excess of that required for working the clocks, the distribution of compressed air was commenced upon a much larger scale for the transmission of power to various parts of Paris, and for a great variety of purposes, ranging from the working of sewing-machines to the driving of printing machinery, electric-light apparatus, elevators, and other appliances. The extension of the works was begun in 1886, and the building now containing the engines and compressors is a rectangular structure open from end to end, 328 ft. long and 66 ft. wide; adjoining, but separate from the engine-room, is the boiler-house, 66 ft. long and 36 ft. wide. The structure is entirely of iron, the spaces between the standards being filled in with brickwork. The first engine erected was a beam-engine of 350 horse-power, and the works, as completed in 1887, contain also a range of six horizontal compound engines. The cylinders of each compound engine are 22 and 35 in. diameter, and 4 ft. stroke; each engine, when working at 50 revolutions per minute, and at the effective steam pressure of 85 lbs. per sq. in., is capable of developing 400 horse-power, making a total of no less than 2,400 horse-power. The air-compression cylinders, one to each steam-cylinder, are 23·62 in. diameter, and are placed on the same bed-plates and driven from the piston-rods of the engines. For cooling the compressed air a jet of water is admitted at each end of the compressing cylinder, and the latter is drained by a trap at each end. The compressed air is delivered from the compressors through spring-loaded valves into seven cylindrical receivers, 6½ ft. diameter and 41 ft. long, placed end to end, and connected together by pipes with valves and by-passes in such a way that any one receiver can be isolated for repairs, or other purposes. The connecting pipes are 12 in. diameter, and are so arranged that, if it is found desirable, the compressors can deliver the air direct into the mains. The cost of water is sufficiently high in Paris to render it desirable that as much economy as possible should be effected in its use. The condensing water from the engines is accordingly collected and pumped up to the top of a large rectangular structure which is provided with seven stages, having a total surface of about 32,000 sq. ft.; in flowing over this large surface the water is cooled on its way to the reservoir upon the top of which this cooler is placed, whence it is brought back to the engines to be used over again; so that only the water required to make up the loss due to evaporation has to be supplied from the city mains." A subway leading from the works gives access to the great system of underground tunnels by which Paris is traversed, and in which, as far as possible, the mains are laid. The pipes are of cast-iron, about 12 in. inside diameter, and the two lines of mains are each laid in duplicate. As in the case of the pipes for working the pneumatic clocks, the two lines of mains are connected at short intervals by cross-pipes, 12 in. diameter, so as to divide up the system into as many distinct sections as possible, and thereby to render the supply as free from the dangers of interruption as is possible. The branch or service pipes from the mains into the premises of the consumers vary from 1¼ to 4 in. diameter. In order to prevent interruption of the service during repairs or addition of new branches, a large number of valves are placed upon the mains, so as to isolate any particular lengths, and to turn the flow of compressed air into special directions. Although before leaving the works the water contained in the air is removed in a separating reservoir, a certain quantity passes into the mains; and unless means were taken to remove it, considerable trouble might result, especially in the smaller service pipes. Accordingly, at intervals, and especially at the lowest parts of the lines,

automatic separating siphons are introduced, which appear to be practically efficient. Before being conducted to a motor, or distributed throughout a building of branch pipes, the compressed air flows into a pressure regulator, which reduces the pressure to a certain extent, and maintains it uniform, so that none of the slight variations in the mains may be transmitted to the motors. From the regulator the air flows through the metre, which records the amount consumed, and after passing through a heating chamber it is delivered direct to the motor. Engines of special design are employed for converting the power of the compressed air into useful work; they vary from motors for driving a sewing-machine up to engines of 100 horse-power. The air is supplied at a main pressure of from 45 to 70 lbs. per sq. in., and at the rate of 1·5 centime per cubic metre reduced to atmospheric pressure. The purposes for which the compressed air is used may be divided into three distinct classes, as follows: First, during the day, for the distribution of motive power, and for ventilation and cooling, etc.; second, at night, for the production of electricity for lighting; third, continuously during the twenty-four hours, for driving the pneumatic clocks. The first service lasts for about ten hours, from eight in the morning till six in the evening; the second from six in the evening till two in the morning in summer, and in winter from four in the afternoon till five in the morning, and in some establishments till daylight. Thus, although the conditions of supply change considerably during each day, and the demand upon the central station, except for the pneumatic clocks, is very variable, the work of the condensers and air-compressors is continuous, and the variations and requirements are sufficiently regular for determining within comparatively narrow limits the quantity of reserve power it is necessary to provide. The principal uses for which the compressed air-supply has already been employed, besides driving the pneumatic clocks, include driving pneumatic motors, for actuating all kinds of machinery, winding up the printing telegraph instruments in the Paris post-offices, shifting wine from one cask to another, raising water from the basement to the top of a house, ringing pneumatic bells, blowing whistles, emptying cesspools, ventilating and cooling rooms, working lifts, shearing metals, cutting stuffs, etc. Prof. A. C. Elliott, in a paper on the "Compound Principle in the Transmission of Power by Compressed Air" (*Engineering*, August 28, 1891, p. 238), points out that the heat dissipated in a compressed-air transmission system is a waste product, but the loss is a minimum when the compression is performed isothermally. Isothermal compression, however, has never been successfully carried out. He therefore proposes the principle of intermediate cooling, the compression being effected in two or more successive stages by a compressor with a corresponding number of properly proportioned cylinders connected by receivers, forming a mechanism analogous, as the case may be, with a compound, a triple, or a quadruple expansion steam-engine, worked, as it were, in the reverse direction. For the purposes of an example designed to show the value of the compound principle, the author has assumed the pressure of six atmospheres absolute, and made allowance for all losses, on the scale that Prof. Kennedy found them to exist in the present machinery at Paris over a distance of four miles. The efficiency of the system is taken to be the ratio of the indicated horse-power in the motor-cylinders to the indicated horse-power in the steam-cylinders of the compressor. The following were quoted in the paper as typical results:

	Efficiency.
Simple compressor and simple motor	39·1 per cent.
Compound compressor and simple motor	44·9 "
Compound compressor and compound motor	50·7 "
Triple compressor and triple motor	55·3 "

Experiments with Air-Compressors.—Prof. Riedler has made experiments with a view of increasing the efficiency of the Popp compressed air system in Paris. His results are described at some length in *Engineering*, March 13 and 20, April 10, and May 1, 1891, from which we abstract the following: "The new installation, called the Central Station of the Quai de la Gare, is laid out on a very large scale, the total generating power provided for being no less than 24,000 horse-power; of this it is intended that 8,000 horse-power will be in operation in 1891, and an extension of 10,000 horse-power in 1892. The power now in course of completion comprises four engines of 2,000 horse-power each. Four batteries of boilers will provide steam for these engines. All the principal mains and steam-pipes are made in duplicate, not only for greater security, but in order that each set of engines and boilers may be connected interchangeably without delay. The Seine supplies an ample quantity of water, but not in a condition either for feeding the boilers, for condensation, or for the air-compressors. Special provisions have therefore to be made to filter the water efficiently before it is used. The engines are vertical triple-expansion engines, and are being constructed by MM. Schneider et Cie., of Creusot, with a guarantee of coal consumption not to exceed 1·54 lb. per horse-power per hour. There are three compressing cylinders in each set of engines, one being above each steam-cylinder. Two of these are employed to compress the air to about 30 lbs. per sq. in., after which it passes into a receiver and is cooled. It is then admitted into the third or final compressing cylinder and raised to the working pressure, at which it flows into the mains." Prof. Riedler's first experiments in improving the efficiency of air-compressors were made with one of the Cockerill compressors in use at the St. Fargeau station. These compressors were designed by MM. Dubois and François, of Seraing. Two of their leading features were the delivery of the compressed air at as low a temperature as possible, and with the relatively high piston-speed of about 400 ft. a minute. The former object is attained by the injection of a very fine water-spray at each end of the water-cylinder, and

its rapid removal with each stroke. The free as well as the compressed air flows through the same passages, one at each end of the cylinder; the inlet-valves being placed at the side of these passages, and the outlet or compressed-air valves at the top, the compressed air entering a chamber above the cylinder, common to both valves, and passing thence to the reservoir. The compressed air-valves, which are 7 in. in diameter, are brought back sharply to their seat at each stroke by a small piston operated by compressed air flowing through a by-pass from the chamber. In the modification made by Prof. Riedler in one of the Cockerill compressors a receiver was placed under the two compressing cylinders. The first stage is completed in the large cylinder, the air being compressed to about 30 lbs. per sq. in.; from this it is discharged into the receiver, where it meets with a spray injection that cools it to the temperature of the water. The final stage is then effected in the smaller cylinder, which, drawing the air from the receiver, compresses it to about 90 lbs., and delivers it to the mains. Prof. Riedler claims to have obtained some very remarkable results. He says that the waste spaces in his modification were much smaller than in the Cockerill compressors, while the efficiency of the apparatus was largely increased. The actual engine duty per horse-power and per hour was raised, as a maximum, to 384 cub. ft. of air at atmospheric pressure, and compressed to 90 lbs. per sq. in., a marked increase on the duty of the compressors in use at the St. Fargeau station. The Cockerill compressors experimented on at the same time showed a maximum duty of 306 cub. ft. of air. The results thus obtained were so satisfactory that the designs were prepared for the great compressors to be operated at the new central station on the Quai de la Gare by the 2,000 horse-power engines. The following table shows the results obtained with these compressors. The final air pressure in all cases was 90 lbs. per sq. in.:

TABLE I.—*Performances of Air-Compressors.*

COMPRESSORS.	Revolutions of engine per minute.	Horse-power absorbed by compressors.	Efficiency.	Amount of air passing through inlet-valves each revolution.	Quantity of air passing through valves per hour.	Cubic feet of air per horse-power and per hour.
COCKERILL COMPRESSORS. Diameter of cylinder, 25·98 in.; stroke, 47·24 in.	40	337	·83	46·61	111·864	281·83
	45	353	·83	46·61	125·844	302·66
	40	342	·88	49·43	118·632	296·65
	46	377	·85	48·02	132·534	298·77
	38·67	324	·88	50·14	116·434	306·19
	38·5	327	·89	50·14	115·818	294·18
	38·6	329	·91	50·84	117·740	305·13
RIEDLER COMPRESSORS. Diameter of low-pressure cylinder, 42·91 in.; diameter of high-pressure cylinder, 26·38 in.; stroke, 47·24 in.	52	615	·985	77·34	241·300	353·50
	60	709	·985	76·98	277·128	353·50
	38	422	·985	77·34	176·330	376·12
	39	424	·985	77·34	181·030	384·60

The mains leading from the St. Fargeau station are 11·81 in. diameter. Those from the new station are 19·16 in. Prof. Riedler investigated the losses in the former due to leakage, and found that they varied between 2·2 per cent of air delivered in a main 600 yds. long to 63 per cent in a main 18,500 yds. long. Experiments were also made on loss of pressure due to resistance. From these experiments it would appear that, assuming a speed of 21 ft. per second, a loss in pressure of one atmosphere would correspond to a distance of 20 kilometres; that is to say, a central station could extend its mains on all sides with a radius of 20 kilometres, and the motors at the ends of the lines would receive the air at a pressure of 15 lbs. less than at the central station. Prof. Riedler states that, as an actually measured result, the velocity of the air through the mains of the St. Fargeau system is 19 ft. 8 in. per second, and that the loss in pressure per kilometre is 0·07 atmosphere. From this it follows that, including the resistance due to the four reservoirs, and other obstructions actually existing, an allowance of one atmosphere loss on a 14-kilometre radius is ample. By increasing the initial pressure of the air much better results can be obtained. A very full account of the details of the compressed air-plant at St. Fargeau station is given in *Engineering*, vol. xlvii, 1889, pp. 163, 638, 685, and 715.

Efficiency of a Compressed Air Plant.—M. François (*Engineering*, June 28, 1889) has made an investigation based on an installation of 6,000 indicated horse-power available for compressing the air. He points out that, in order to obtain a cube metre of air at an effective pressure of 85·3 lbs. per sq. in., the engines should develop 1,207,911 foot-pounds in the steam-cylinders. A cube metre of air compressed to 85·3 lbs. per in., and at a mean temperature of 53°, weighs 18·55 lbs., and involves the compression of 242 cub. ft. of air. To this work, which represents the expenditure of power upon the air delivered into the reservoir, has to be added that absorbed by the flow of the compressed air through the mains, the velocity of which, to obtain the most economical results, ought not, it is stated, to exceed 26 ft. per second; the experience of the Paris company appears to have established this rate, and the mains are made sufficiently large to maintain it as closely as possible. Under such favorable conditions the loss, it is claimed, will not exceed 7·1 lbs. per sq. in., involving an additional work of 39,781 foot-pounds, and bringing the total expenditure upon the cube metre of air, delivered to the subscriber at 85 lbs. per sq. in., to 1,207,911 plus 39,781, making a total of 1,247,692 foot-pounds, which is the total amount of work that has to be exerted by the steam-engine—a duty which will be always guaranteed by any responsible maker of steam-engines and air-compressors. M. François then passes on to consider the amount of useful

work that can be obtained from this cube metre of air delivered into a suitable motor, that being the main point at issue, and upon which the economy of the system depends. To obtain the highest amount of duty, M. Popp introduced the method of heating the air before allowing it to pass into the motors, as has already been explained, and in many cases he has also adopted the practice of injecting a small spray of water into the air so heated. It is stated that a number of experiments made at the St. Fargeau station of the Compressed Air Company showed that, if the efficiency of the air before it is heated be represented by 1, this efficiency will be raised to 1·42 by heating the air to 200° C.; and if a jet of water be injected into this heated air the efficiency will be raised to 1·90. Making a full allowance for waste arising from leakage, lost spaces in the motor, etc., the cube meter of air compressed to 85·3 lbs. per sq. in. would perform useful work, equal to 578,640 foot-pounds in the cylinder of the air motor; if heated at 200°, this efficiency would be raised to 810,000 foot-pounds, and with the water injection to 1,084,900 foot-pounds. As the work done in the steam-cylinder was 1,247,692 foot-pounds, it follows that under these last and most favorable conditions the efficiency of the air motor would rise as high as 8·69 per cent. It is claimed that this large increase in duty is secured by a very small expenditure of fuel and water, amounting to no more per horse-power and per hour than ·44 lb. of coke and 6·6 lbs. of water. For small motors the air is heated by a gas-jet, as we have already explained. If the above figures are correct, the expense incurred for heating and water injection does not exceed one tenth of a penny per horse-power and per hour. From the experiments made at St. Fargeau, M. François has prepared the following table:

TABLE II.—*Efficiency of Compressed Air under Different Conditions.*

	Cold air.	Heated air.	Heated and saturated air.
1. Weight of air used per indicated horse-power per hour in the cylinder of the air motor....lb.	109·88	78·500	58·600
2. Volume of air measured at the exhaust per indicated horse-power per hour in the cylinder of the air motor....cub. ft.	1,363	974	770
3. Temperature of compressed air delivered to the motor....deg. C.	20	200	200
4. Temperature of air at the exhaust....deg.	−55	....	−50
Percentage of efficiency....	·462	·648	·869

This table shows that under the most favorable circumstances the compressed air delivered to a motor, even through a long length of main, will give out more than 85 per cent of the work that was exerted to compress it. In investigating the actual cost, M. François assumes, however, that in practice the duty will not exceed 80 per cent. Prof. Riedler considers that results as favorable as those given by compressed air can not be given by any other means of transmission, and for the following reasons: Power transmission of any kind involves several conversions, each of which is attended with a certain percentage of loss; these various stages are, apart from the generation of steam, a primary motor; mechanical appliances for the conversion of the energy of this motor into another form convenient for transmission; its transmission through mains, conductors, or by other means; and the receiving-engine which is worked by the remnant of energy distributed from the central station. Allowing the smallest percentage of loss in each of these stages, a percentage which would certainly never be obtained in practice, it will be found that the work done by the second or receiving motor can not be more than 65 per cent of that developed at the central station. But, by using compressed air which has been heated before admission, it is claimed that an efficiency of 80 per cent has been obtained under circumstances not at all favorable. In the trials of the "Journeaux" engines, 54 per cent efficiency is recorded, with a consumption of 695·7 cub. ft., although this engine, when worked by steam, for which it was designed, showed a loss of 25 per cent. The losses in the primary engine, in the compressors, and in the mains, have to be included in the difference between 54 per cent measured and the 75 per cent of possible efficiency due to the Journeaux engine.

Utilization of Compressed Air in Small Motors.—The transmission of the compressed air is attended with loss, which increases with length of the transmission, leakage, etc. In the Popp system in Paris there has been adopted a cast-iron stove lined with fire-clay, heated either by a gas-jet or by a small coke-fire. The economy resulting will be seen from the following table:

TABLE III.—*Efficiency of Air-heating Stoves.*

NATURE OF STOVE.	Heating surface.	Air heated per hour.	TEMPERATURE OF AIR IN OVEN. Admission. Deg. C.	TEMPERATURE OF AIR IN OVEN. Exit. Deg. C.	VALUE OF HEAT ABSORBED PER HOUR. Total.	VALUE OF HEAT ABSORBED PER HOUR. Per square foot of heating surface.	VALUE OF HEAT ABSORBED PER HOUR. Per pound of coke.
	Sq. ft.	Cub. ft.			Calories.	Calories.	Calories.
Cast-iron box-stoves....	14	20,342	7	107	17,900	1,278	2,032
	14	11,054	7	184	17,200	1,228	2,058
Wrought-iron coiled tubes....	46·3	38,428	50	175	39,200	830	2,545

The results given in this table were obtained from a large number of trials. From these trials it was found that more than 70 per cent of the total number of calories in the fuel

employed was absorbed by the air, and transformed into useful work. Whether gas or coal be employed as the fuel, the amount required is so small as to be scarcely worth consideration; according to the experiments carried out it does not exceed ·09 kilogramme per horse-power and per hour, but it is scarcely to be expected that in regular practice this quantity is not largely exceeded. Prof. Weyrauch claims that the efficiency of fuel consumed in this way is six times greater than when burned under a boiler to generate steam. According to Prof. Riedler, from 15 to 20 per cent above the power at the central station can be obtained by means at the disposal of the power-users; and it has been shown by experiment that the heating the air to 250° C., as an increased efficiency of 30 per cent can be obtained. The utilization of compressed air, especially as regards the motors, is still in a very imperfect stage, and a great deal remains to be done before the maximum power available at the motor can be obtained. Investigations in this direction for a considerable time to come must be directed, therefore, toward improving the design and construction of the motors, and the treatment of the air at the point of delivery into the engine. A large number of motors in use among the subscribers to the Compressed Air Company of Paris are rotary-engines developing 1 horse-power and less, and these, in the early times of the industry, were extravagant in their consumption to a very high degree; to some extent this condition of things has been improved, chiefly by the addition of better regulating valves to control the air admission. The efficiency of this type of rotary motors, with air heated to 50°, may now be assumed at 43 per cent—not a very economical result, it is true, and one that may be largely improved; yet it is evident that with such an efficiency the use of small motors in many industries becomes possible, while, in cases where it is necessary to have a constant supply of cold air, economy ceases to be a matter of the first importance. Small rotary-engines working cold air without expansion used as high as 2,330 cub. ft. of air per brake horse-power per hour, and with heated air 1,624 cub. ft. Working expansively, a 1-horse-power rotary-engine used 1,469 cub. ft. of cold air, or 960 cub. ft. of heated air; and a 2-horse-power rotary-engine 1,059 cub. ft. of cold air, or 847 cub. ft. of air heated to about 50° C. The following table shows the results of test of a small rotary-engine used for driving sewing-machines, and indicating about a tenth of a horse-power:

TABLE IV.—*Trials of a Small Riedinger Rotary-Engine.*

NUMBERS OF TRIALS	1	2
Initial air pressure ... lb. per sq. in.	86	71·8
Initial temperature of air ... deg. C.	+12	+170
Foot-pounds per second measured on the brake	51·63	34·07
Revolutions per minute	384	300
Consumption of air for one horse-power per hour	1,377	988

The following table shows the results obtained with a ½-horse-power variable expansion Riedinger rotary-engine. These trials represent the best practice that has been obtained up to the present time (1890). The volumes of air were in all cases taken at atmospheric pressure:

TABLE V.—*Trials of a Small ½-Horse-Power Riedinger Rotary-Engine.*

NUMBERS OF TRIALS	1	2	3	4
Initial pressure of air ... lb. per sq. ft.	54	69·7	85	71·8
Initial temperature of air ... deg. C.	170	180	198	8
Final temperature of air ... "	25	20	....	25
Revolutions per minute	355	350	310	243
Foot-pounds per minute measured on brake	271	477	376	316
Consumption of air per horse-power and per hour	883	791	900	1,148

AIR-COMPRESSORS. Improvements in apparatus for compressing air have recently been made, chiefly in the direction of increasing the speed of rotation, so as to lessen the size and consequent first cost of a machine to do a given quantity of work. The limitation to the speed of an air-compressor has generally been that of the motion of the air-valves, which automatically open and shut with each reversal of the position. To overcome this limitation positive air-valves have been introduced, which receive their motion by mechanical connection with some moving part of the engine. Some large blowing-engines for Bessemer steel-works have been thus constructed. The problem of a positive valve-movement, as related to the suction-valves, is a simple one, but as related to the discharge-valves is difficult of solution. The difficulty of the problem arises from the fact that the discharge-valves should not open at a fixed point in the stroke, but at a point depending upon the pressure of the air carried, upon the altitude above sea-level, the barometric pressure, and other factors beyond control.

The Rand Drill Company's Compressor.—Figs. 1 and 2 illustrate the Halsey gear as made by the Rand Drill Company, which is designed to meet the varied requirements imposed by the discharge-valve. It retains the poppet-valve, which experience has shown to be peculiarly adapted to the requirements of air-compressors, for the reason that such valves have little tendency to wear leaky, and, moreover, any slight leak that may develop is easily repaired by hand-grinding. Fig. 1 is a sectional view of an air-cylinder with the gear applied. The principle of this gear is very simple. The usual form of valve chatters because the air

tries to pull it open while the spring tries to pull it shut, and first one and then the other prevails. This device dispenses with the spring, the valve being opened in the usual way by

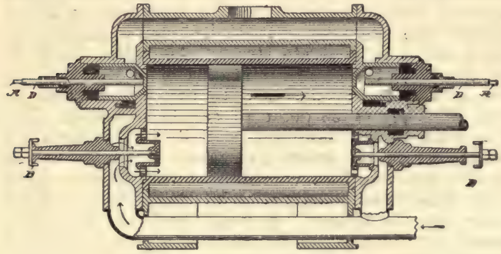


FIG. 1.—Rand compressor.

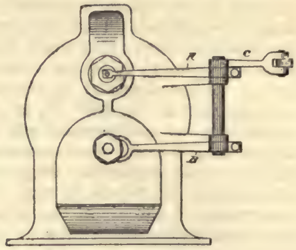


FIG. 2.—Rand compressor.

the air-pressure, and closed at the proper time—the end of the stroke—by a positive moving mechanism. This mechanism being released when the valve is open, the valve is freed from any influence tending to close it, and it hence opens to its full width and stays open. The chattering being avoided, it becomes practicable to give the valve a full lift, instead of the restricted lift necessary with the usual spring-pressed valve. The increased area thus obtained cuts down the number of valves necessary for the required passageway—a single inlet and a single outlet, giving, under usual conditions, considerably more opening than the combined opening of the nest of valves previously used. The longitudinal section of the cylinder is shown in Fig. 1, from which the construction of the valves is seen, these valves being operated by levers A and B, mounted upon a common rock shaft, as shown in Fig. 2. The movement of these levers toward the observer closes the suction-valves at the bottom by the lever B, while the movement from the observer closes the discharge-valve through the lever A and rod D. Lever C is connected with a corresponding lever belonging to the opposite end of the cylinder by means of a link-rod, the whole system of levers being thus connected and moving together. The most peculiar feature of the device is that it fulfills perfectly the varied requirements of the discharge-valve, without any additional mechanism whatever. The movement of the levers is so timed that the discharge-valve is at liberty to open soon after the commencement of the compression-stroke, the actual opening occurring whenever the cylinder-pressure equals the reservoir-pressure, no matter what that pressure may be, nor in what part of the stroke the equality of pressure is established. Fig. 3 represents another gear, of similar appearance but different principle, made by the Rand Drill Company. In this gear the springs are retained, but during the time any given valve is open the springs are pressed back by the arms a, b, and their tendency to close the valves and cause chattering is thus obviated. This gear has the same advantage as the last in reducing the number of valves required for a given area of opening. A perspective view of one of the largest Rand compressors is given in one of the full-page plates.

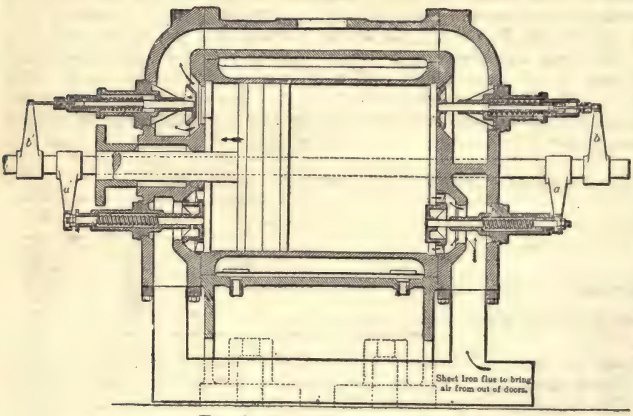


FIG. 3.—Rand Compressor.

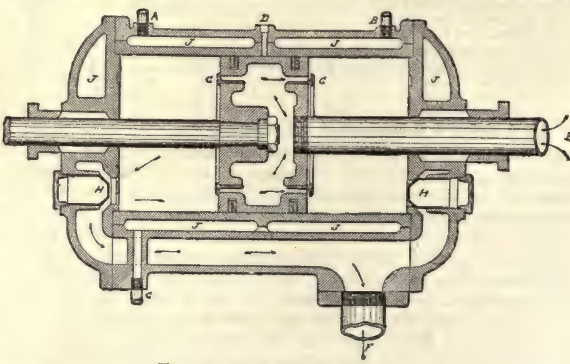
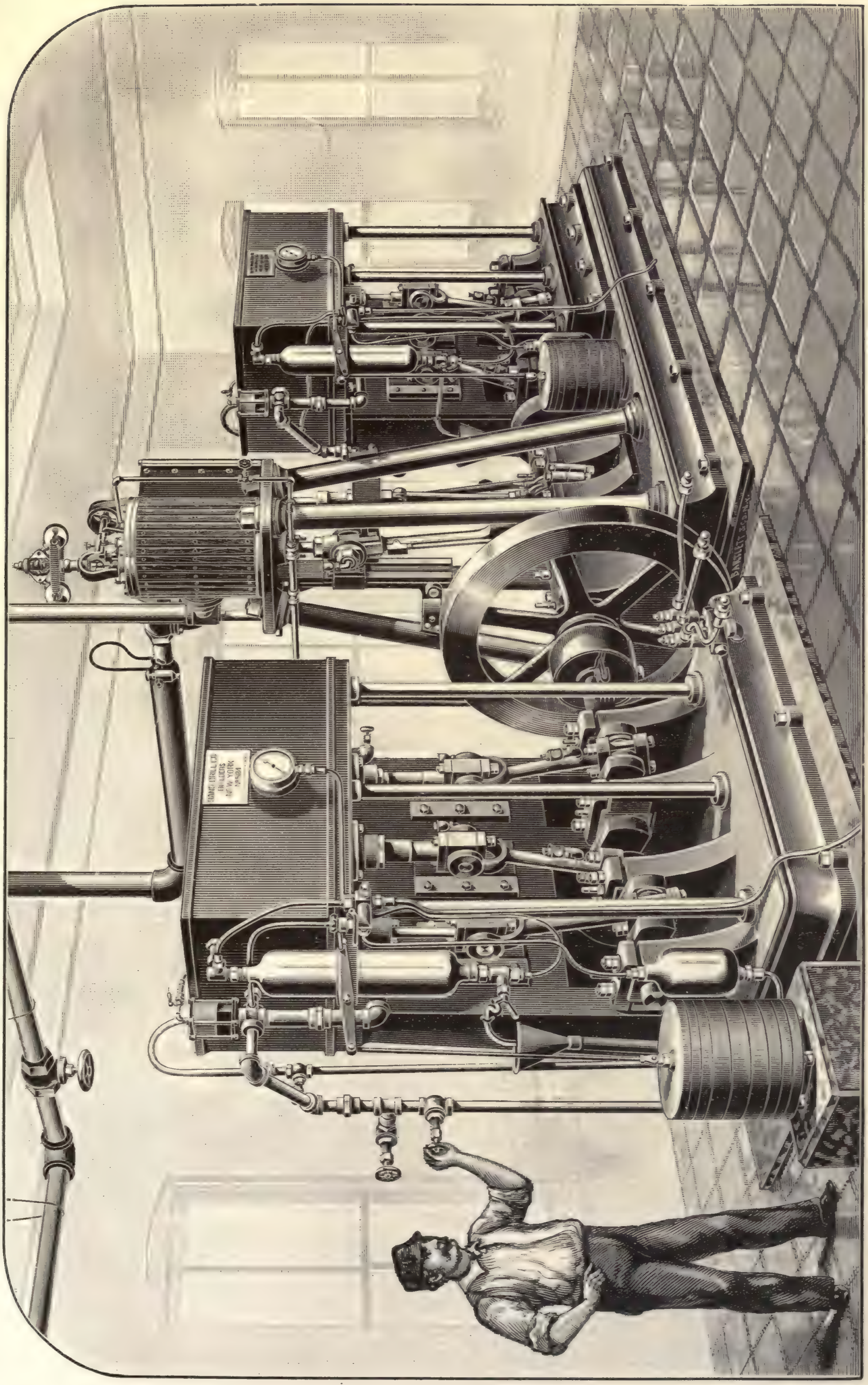


FIG. 4.—Sergeant compressor.

Sergeant's Concentrated Piston Inlet Compressor is shown in section in Fig. 4. Referring



to the letters on the cut, A is the cold-water inlet; B, the cold-water discharge; C, the jacket drain; D, oil-hole for oil-cup; E, air-inlet; F, air-delivery; G, inlet-valves; H, delivery-valves; J, cold-water jacket. The air-inlet valves are large metallic rings, Fig. 5, which open and close by the natural momentum given to the valve by the movement of the piston. A study of the cut will show that when the piston is moving in one direction, the ring-valve on that face of the piston which is toward the direction of movement is closed, while that on the other face is open. This is as it should be, in order to discharge the compressed air from one end of the cylinder while taking in the free air at the other. The position of each valve is almost instantaneously reversed at the point when the stroke is reversed. This change of position takes place without springs or other influence than the natural momentum of a piece of metal which is carried in one direction and is instantly reversed. The large ring air-inlet valves admit of a large area of inlet with but a small throw of valve, thus quickly opening a large supply port, and enabling a compressor to run at high speed without a reduction of efficiency, and with safety to the quick-moving parts. There being no inlet-valves in the heads of the air-cylinder, the space otherwise occupied by these valves is filled with cold water, thus presenting a cooling surface to the compressed air near the end of the stroke when the air is hottest. This gives all the advantages of cooling by water-injection, without the disadvantages incident upon bad water, and the necessity of moving a body of water back and forth in the cylinder. The discharge-valves on the Ingersoll-Sergeant compressors are shown in Fig. 6. Fig. 7 illustrates the unloading device and regulator as applied to the Ingersoll-Sergeant air-compressor. The purpose of this unloading device is to maintain a uniform air-pressure in the receiver and a uniform speed of engine, notwithstanding the consumption of the air, and to do this without waste of power or attention on the part of the engineer. A weighted valve of safety-valve pattern is attached to the air-cylinder, and is connected with the air-receiver, and with a discharge-valve on each end of the air-cylinder, also with a balanced throttle-valve in the steam-pipe. When the pressure of the air gets above the desired point in the receiver, the valve is lifted and the air is exhausted from behind the discharge-valves, thus letting the compressed air at full-receiver pressure into the cylinder at both ends, and balancing the engine. At the same instant the compressed air is exhausted from the little piston connected with the balanced steam-valve and the steam is automatically throttled, so that only enough steam is admitted to keep the engine turning around, or to overcome the friction, no work being done. When the compressor is unloaded, it is evident that the function of the air-piston is merely to force the compressed air through the discharge-valves and passages from one end to the other until more compressed air is required, this being indicated by a fall in the receiver-pressure. The weighted

FIG. 5.

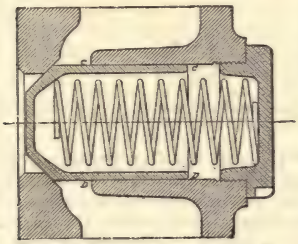


FIG. 6.—Sergeant compressor.

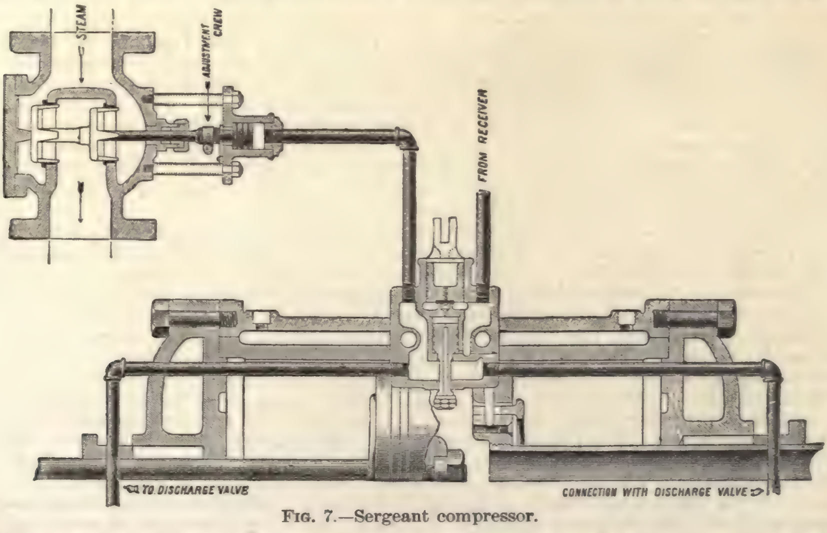


FIG. 7.—Sergeant compressor.

valve now closes, and the small connecting-pipes are instantly filled with compressed air; the steam-valve automatically opens, and the compression goes on in the regular way. Another function of this device is to prevent the compressor from stopping or getting on the center. Direct-acting compressors are liable to center when doing work at slow speed.

The Norwalk Compound Air-Compressor is shown in outline in Fig. 8. The lettering on the cut refers to the several parts as follows: A, inlet conduit for cold air; B, removable

hoods of wood; *C*, inlet valve; *D*, intake cylinder; *E*, discharge-valve; *F*, intercooler; *G*, compressing cylinder; *H*, discharge air-pipe; *J*, steam-cylinder; *K*, steam-pipe; *L*, exhaust steam-pipe; *N*, swivel connection for crosshead; *O*, air relief-valve, to effect easy starting

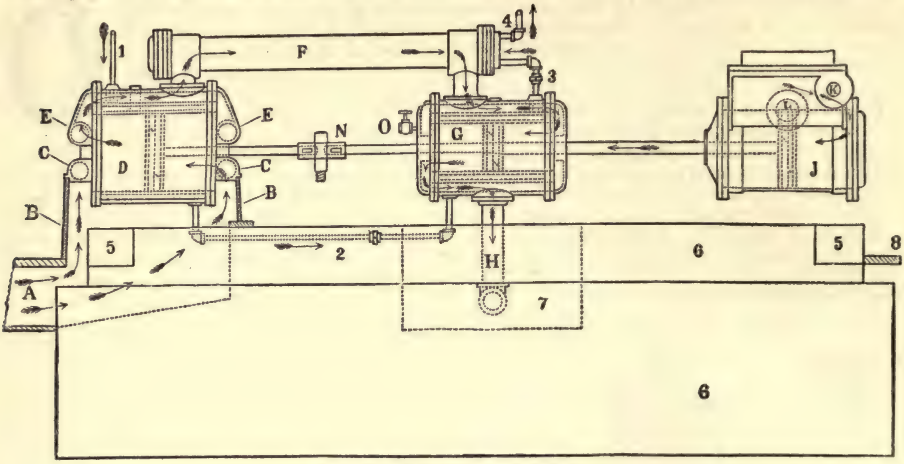


Fig. 8.—Norwalk compressor.

after stopping with all pressure on the pipes; 1, cold-water pipe to cooling jacket; 2 and 3, water-pipe; 4, water overflow or discharge; 5, stone on end of foundation; 6, foundation; 7, space to get at underside of cylinder; 8, floor-line. Arrows on the water-pipes show the direction of water circulation. When pistons move as indicated by the arrow on the piston-rod, steam and air circulate in direction shown by arrows in the cylinders. The air is admitted to the cylinder by valves of the well-known Corliss steam-engine pattern, which have a positive movement from the main shaft. The port is large, is clear of obstructions, and opens directly into the cylinder. The action of the forces in a compound air-compressor are described as follows: The large air-cylinder on the left determines the capacity of the compressor, and for illustration its piston is taken at 100 sq. in. area. The small air-cylinder in the center can have an area of $33\frac{1}{3}$ sq. in. The small piston only encounters the heaviest pressure, and at 100 lbs. pressure the resistance to its advance is 3,333 lbs. The resistance against the large piston is its area multiplied by the pressure which is caused by forcing the air from the large cylinder into the smaller cylinder, which is in this case 30 lbs. per sq. in. But as this 30 lbs. pressure acts on the back of the small piston and hence assists the machine, the net resistance of forcing the air from the large into the small cylinder is equal to the difference of the area of the two pistons multiplied by the 30 lbs. pressure. This is $66\frac{2}{3}$ by 30 and equals 1,999 lbs. Hence 1,999 lbs. the resistance to forcing the air from the large into the smaller cylinder plus 3,333 lbs. the resistance in the smaller cylinder to compressing it to 100 lbs. is the sum of all the resistances in the compound cylinders at the time of greatest effort. This is 5,333 lbs. The time of greatest effort is at the end of the stroke, or when the engine is passing the center. In the single machine this resistance would be 10,000 lbs., hence in the compound machine the maximum strains are less by over 46 per cent, or nearly one half. By thus reducing the work to be done at the end of the stroke, more work is done in the first part of the stroke, and the resistance is made nearly uniform for the whole stroke.

Water Injection.—The practice of injecting water into the air-cylinders of compressors is now generally discontinued by American makers. The relative advantages and disadvantages of this water injection are thus summed up by William L. Saunders, in his pamphlet on Compressed-Air Production (1891): "Two systems are in use by which the heat of compression is absorbed, and the difference between one and the other is so distinct that air-compressors are usually divided into two classes: 1, wet compressors; 2, dry compressors. A wet compressor is that which introduces water directly into the air-cylinder during compression. A dry compressor is that which introduces no water into the air during compression. Wet compressors may be subdivided into two classes: 1, those which inject water in the form of a spray into the cylinder during compression; 2, those which use a water-piston for forcing the air into confinement. The injection of water into the cylinder is usually known as the Colladon idea. Compressors built on this system have shown the highest isothermal results—that is, by means of a finely divided spray of cold water the heat of compression has been absorbed to a point where the compressed air has been discharged at a temperature nearly equal to that at which it was admitted to the cylinder. The advantages of water injection during compression are as follows: 1. Low temperature of air during compression. 2. Increased volume of air per stroke, due to filling of clearance spaces with water and to a cold-air cylinder. 3. Low temperature of air immediately after compression, thus condensing moisture in the air-receiver. 4. Low temperature of cylinder and valves, thus maintaining packing, etc. 5. Economical results, due to compression of moist air (see Table III). The first advantage is by far the most important one, and is really the only excuse for

water injection in air-compressors. The percentage of work of compression which is converted into heat and loss when no cooling system is used is as follows: Compressing to 2 atmospheres, loss 9·2 per cent; to 3, 15·0 per cent; to 4, 19·6 per cent; to 5, 21·3 per cent; to 6, 24·0 per cent; to 7, 26·0 per cent; to 8, 27·4 per cent. We see that in compressing air to five atmospheres, which is the usual practice, the heat loss is 21·3 per cent, so that, if we keep down the temperature of the air during compression to the isothermal line, we save this loss. The best practice in America has brought this heat loss down to 3·6 per cent (old Ingersoll injection air-compressor), while in Europe the heat loss has been reduced to 1·6 per cent. Introducing water into the air-cylinder in any other way, except in the form of a spray, has but little effect in cooling the air during compression. On the contrary, it is a most fallacious system, because it introduces all the disadvantages of water injection without its isothermal influence. Water, by mere surface contact with the air, takes up but little heat, while the air, having a chance to increase its temperature, absorbs water through the affinity of air for moisture, and thus carries over a volume of saturated hot air into the receiver and pipes, which on cooling, as it always does in transit, deposits its moisture and gives trouble through water and freezing. It is therefore of much importance to bear in mind that, unless water can be introduced during compression, to such an extent as to keep down the temperature of the air in the cylinder, it had better not be introduced at all. If too little water is introduced into an air-cylinder during compression, the result is warm, moist air; and if too much water is used, it results in a surplus of power required to move a body of water which renders no useful service. Table II (p. 20) deduced from Zahner's formula gives the quantity of water which should be injected per cubic foot of air compressed in order to keep the temperature down to 104° F. Objections to water injections are as follows: 1. Impurities in the water, which, through both mechanical and chemical action, destroy exposed metallic surfaces. 2. Wear of cylinder, piston, and other parts, due directly to the fact that water is a bad lubricant, and, as the density of water is greater than that of oil, the latter floats on the water and has no chance to lubricate the moving parts. 3. Wet air arising from insufficient quantity of water and from inefficient means of ejection. 4. Mechanical complications connected with the water-pump, and the difficulties in the way of proportioning the volume of water and its temperature to the volume, temperature, and pressure of the air. 5. Loss of power required to overcome the inertia of the water. 6. Limitations to the speed of the compressor, because of the liability to break the cylinder head-joint by water confined in the clearance spaces. 7. Absorption of air by water." Mr. John Darlington, of England, gives the following particulars of a modern air-compressor of European type: "Engine, two vertical cylinders, steam jacketed with Meyer's expansion gear. Cylinders, 16·9 in. diameter, stroke 39·4 in.; compressor, two cylinders, diameter of piston, 23·0 in.; stroke, 39·4 in.; revolutions per minute, 30 to 40; piston-speed, 39 to 52 in. per second; capacity of cylinder per revolution, 20 cubic ft.; diameter of valves, viz., four inlet and four outlet, 5½ in.; weight of each inlet valve, 8 lbs.; outlet, 10 lbs.; pressure of air, 4 to 5 atmospheres. The diagrams taken of the engine and compressor show that the work expended in compressing one cubic metre of air to 4·21 effective atmospheres was 38,128 lbs. According to Boyle and Mariotte's law it would be 37,534 lbs., the difference being 594 lbs., or a loss of 1·6 per cent. Or if compressed without abstraction of heat, the work expended would in that case have been 48,158. The volume of air compressed per revolution was 0·5654 cubic metre. For obtaining this measure of compressed air, the work expended was 21,557 lbs. The work done in the steam-cylinders, from indicator diagrams, is shown to have been 25,205 lbs., the useful effect being 85½ per cent of the power expended. The temperature of air on entering the cylinder was 50° F., on leaving 62° F., or an increase of 12° F. Without the water-jacket and water injection for cooling the temperature, it would have been 302° F. The water injected into the cylinders per revolution was 0·81 gallon." We have in the foregoing a remarkable isothermal result. The heat of compression is so thoroughly absorbed that the thermal loss is only 1·6 per cent.; but the loss *by friction of the engine* is 14·5 per cent, and the net economy of the whole system is no greater than that of the best American dry compressor, which loses about one half the theoretical loss due to heat of compression, but which makes up the difference by a low friction loss.

The wet compressor of the second class is the water-piston compressor. In America, a plunger is used instead of a piston, and as it always moves in water the result is more satisfactory. The piston, or plunger, moves horizontally in the lower part of a U-shaped cylinder. Water at all times surrounds the piston, and fills alternately the upper chambers. The free air is admitted through a valve on the side of each column and is discharged through the top. The movement of the piston causes the water to rise on one side and fall on the other. As the water falls the space is occupied by free air, which is compressed when the motion of the piston is reversed and the water column raised. The discharge-valve is so proportioned that some of the water is carried out after the air has been discharged. Hence there are no clearance losses. Hydraulic piston compressors are subject to the laws that govern piston-pumps, and are therefore limited to a piston-speed of about 100 ft. per minute. It is out of the question to run them at much higher speed than this without shock to the engine and fluctuations of air-pressure due to agitation of the water-piston. We have seen that it is possible to lose 21·3 per cent of work when compressing air to five atmospheres without any cooling arrangements. With the best compressors of the dry system one half of this loss is saved by water-jacket absorption, so that we are left with about 11 per cent, which the slow-moving compressor seeks to erase, but in which the friction loss alone is greater than the heat loss which is responsible for all the expense in first cost and in main-

tenance of such a compressor, but which really is not saved unless water injection in the form of spray forms a part of the system.

Useful Tables.—Mr. Saunders, in his pamphlet, gives the following useful tables relating to the compression of air:

TABLE I.—*Heat produced by Compression of Air.*

Atmospheres.	PRESSURE. Pounds per square inch above a vacuum.	PRESSURE. Pounds per square inch above the atmosphere (gauge pressure).	Volume in cubic feet.	Temperature of the air throughout the process.	Total increase of temperature.
				Degrees.	Degrees.
1·00	14·70	0·00	1·0000	60·0	00·0
1·10	16·17	1·47	0·9346	74·6	14·6
1·25	18·37	3·67	0·8536	94·8	34·8
1·50	22·05	7·35	0·7501	124·9	64·9
1·75	25·81	11·11	0·6724	151·6	91·6
2·00	29·40	14·70	0·6117	175·8	115·8
2·50	36·70	22·00	0·5221	218·3	158·3
3·00	44·10	29·40	0·4588	255·1	195·1
3·50	51·40	36·70	0·4113	287·8	227·8
4·00	58·80	44·10	0·3741	317·4	257·4
5·00	73·50	58·80	0·3194	369·4	309·4
6·00	88·20	73·50	0·2806	414·5	354·5
7·00	102·90	88·20	0·2516	454·5	394·5
8·00	117·60	102·90	0·2288	490·6	430·6
9·00	132·30	117·60	0·2105	523·7	463·4
10·00	147·00	132·30	0·1953	554·0	494·0
15·00	220·50	205·80	0·1465	681·0	621·0
20·00	294·00	279·30	0·1195	781·0	721·0
25·00	367·50	352·80	0·1020	864·0	804·0

TABLE II.—*Injection Water required to keep Temperature constant.*

Compression by atmosphere above a vacuum.	Heat units developed in 1 lb. free air by compression.	Weight of water to be injected at 68° F. to keep the temperature at 104° F. in pounds of water and per pound of free air.	Weight of water to be injected at 68° F. to keep the temperature at 104° F. in pounds of water for 1 cub. ft. of free air.
2	3·702	0·734	0·056
3	5·867	1·664	0·089
4	7·406	1·469	0·113
5	8·598	1·701	0·131
6	9·570	1·891	0·145
7	10·398	2·063	0·158
8	11·109	2·204	0·167
9	11·740	2·329	0·179
10	12·301	2·440	0·188
11	12·813	2·542	0·195
12	13·278	2·634	0·202
13	13·706	2·719	0·209
14	14·102	2·798	0·215
15	14·471	2·871	0·223

TABLE III.—*Showing the Relative Quantity of Work required to compress a given Volume and Weight of Air, both Dry and Moist; also Relative Volumes with and without Increase of Temperature from Compression.*

Tension in atmospheres.	COMPRESSION AT A CONSTANT TEMPERATURE. MARIOTTE'S LAW. Volume.	Work of compression. Cubic metres in kilogram-metres.	Work of compression. Cubic feet in foot-pounds.	COMPRESSION WITH INCREASE OF TEMPERATURE. Volume.	Work of compression. (Dry.) Cubic metres in kilogram-metres.	Work of compression. (Dry.) Cubic feet in foot-pounds.	Temperatures. (Dry.) Cent.	Temperatures. (Dry.) Fahr.	Ratio of greater to less temperature Absolute.	Loss of work in compressing one cubic metre in kilogram-metres. By increase of temperature alone.	Percentage of work of compression converted into heat and lost. By increase of temperature alone.	Final temperature if water is used in compression.	Percentage of water to air required.	FOOT-POUNDS TO COMPRESS ONE POUND AIR. Dry.	FOOT-POUNDS TO COMPRESS ONE POUND AIR. With sufficient moisture.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
			Deduced from 3.			Deduc'd from 6.						Fahr.			
1	0·1	......	......	.....	......	.....	20	68	1·0	......	.....	68	...	......	......
2	0·5	7,199	1,468	0·612	7,932	1,618	85·5	186	1·222	733	0·092	111	3·0	23,500	22,500
3	0·333	11.356	2,316	0·459	13,360	2,725	130·4	267	1·375	2,004	0·150	135·5	4·0	37,000	35,000
4	0·25	14,260	2,909	0·374	17,737	3,618	165·6	330	1·495	3,477	0·196	153·5	4·8	48,500	45.000
5	0·200	16,580	3,383	0·320	21,209	4,326	195·3	384	1·595	4,629	0·213	167	5·4	58,500	52,500
6	0·167	18,475	3,768	0·281	24,310	4,959	220·5	429	1·681	5,835	0·240	179	6·0	67,000	60.000
7	0·143	20,038	4,087	0·252	27,048	5,517	243·2	470	1·758	7,040	0·260	190	6·4	75,000	66.000
8	0·125	21,422	4,370	0·229	29,518	6,021	263·6	506·5	1·828	8,096	0·274	.....	...	......	......
9	0·111	......	......	0·210	......	.....	282	539·6	1·891	......	......	.....	...	......	......
10	0·100	......	......	0·195	......	.....	299	570·2	1·950	.....	.....	.....	...	....	.....

AIR-HOIST. Fig. 1 shows a pneumatic hoist that has recently been introduced by Pedrick & Ayer, of Philadelphia, as a substitute for the commonly used chain hoists and blocks. The cylinder is made of extra strong wrought-iron pipe, which is carefully reamed out; to the upper head is fastened an ordinary pipe-cap, to which there is attached a hook by which the hoists can be readily hung to the overhead trolley, and, if desired, the hoist can be transferred to different parts of the shop. The lower head is made of two castings, one of which is screwed to the end of the cylinder and has a lug to receive a screw-end of the valve which supplies the air for lifting. By this construction the piston can not travel below the air-opening, which would interfere with the proper operation of the hoist. To this lower ring is attached a head, which is held in place by four small studs and nuts; this head also contains the stuffing-box for packing around the piston-rod; by this construction the lower head can be readily removed for an examination of the piston and its packing without in any way disturbing the hoist. The piston is of simple design, consisting of a cast-iron head, follower-plate, and a leather cup-ring, which adjusts itself to the cylinder and prevents leakage. The lower end of the piston-rod has a swivel, which allows the ring to be turned to any desired position in the rod. The piston acts but one way, as it has been found that the weight of the load, or even the piston-rod and head, is sufficient to allow it to drop when the pressure from the lower end is relieved.

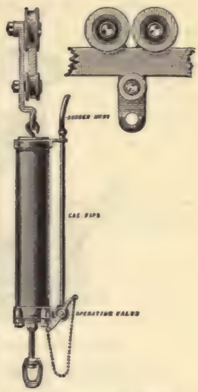


Fig. 1.—Air-hoist.

The valve consists of but four parts: a body, valve-stem, cap, and small spring to keep the valve-stem in place, which, with the air pressure, keeps the stem in constant pressure against the body. One side of the valve is provided with a lug, by which it is attached to the lower ring of the hoist. The power is supplied by an air-compressor, one of which is 6″ to 8″ in diameter, with a storage tank of about 3′ in diameter and 5′ long, which will supply sufficient compressed air for 12 to 18 hoists having average use. For special purposes, such as where the hoist is used constantly, a less number can be supplied by a compressor of the above size. Hose is attached to the upper end of the wrought-iron pipe, the length of the hose depending upon the floor area which it is desired the hoist should cover. About 80 lbs. air pressure is generally used.

AIR-TOOL. McCoy's pneumatic tool consists of an automatic hammer reciprocated in a cylinder by compressed air, or by steam, which delivers a rapid succession of blows upon a tool-holder into which are inserted suitable bits or chisels for cutting wood, metal, or stone. It embraces in its details valves for admitting and exhausting the air, a provision for relieving the cylinder and piston from injurious friction, and for cushioning the piston and holding the bit-socket in position, to facilitate its easy and steady application to the work. It has been applied successfully to the calking of steam-boilers, the chasing of silverware, répoussé-work, stone-dressing, and sculpture. The Committee on Science and Arts of the Franklin Institute made a report recommending the award of a medal for this invention, and from their report (*Journal of the Franklin Institute*, July, 1889) we extract the following description: "As exhibited to the committee it was working at a very high speed, from the pitch of the sound probably more than 5,000 strokes per minute. The instrument, as complete and connected ready for action, appears in the form of a short cylinder, having a flexible tube centrally connected to one end, through which compressed air or steam is supplied at a pressure of about 40 lbs. per sq. in., and centrally at the other end a guide or sleeve, in which the tool-holder reciprocates; into the socket of the tool-holder the cutting bits, chisels, or hammers are inserted. Upon disengaging a latch by pressing a button, the ends of the cylindrical case can be unscrewed, and inside of the shell or cover is found a working cylinder, with grooves on its outer surface and passages leading from the flexible tube at the center of the upper cylinder-head to one slotted chamber in the outside of the working cylinder, and terminating in inlet ports leading into the interior of the working cylinder. Another slotted chamber in the external surface of the working cylinder leads from reduction ports through the cylinder, and terminates in a channel leading to the atmosphere through the head of the cylinder. The piston is made long and fits fluid-tight, but with a minimum of friction in the cylinder. In the piston, but working transversely through it, is a piston-valve, which is worked by the pressure of air admitted through the port in the side of the cylinder and exhausted through other ports in the same manner as the piston-valves of some steam-pumps, the proper ports in the cylinder being covered and uncovered by the motion of the piston. The valve consists of a cylindrical plug having two grooves formed therein with a collar between them, and fits in a cylindrical transverse seat in the piston, and covers and uncovers, at proper intervals, admission and exhaust ports leading

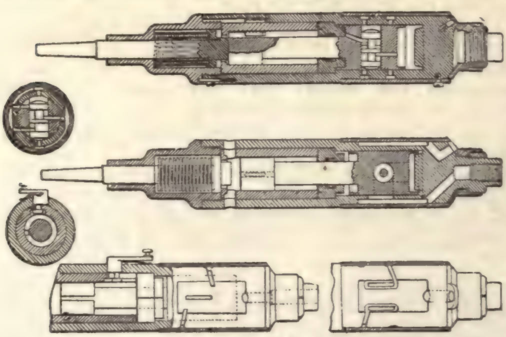


Fig. 1.—Air-tool.

to the ends of the working cylinder. The piston is not attached or connected to the tool-holder, but strikes upon it as a ram or hammer; a spiral spring placed around the tool-holder, and resting with one end on a shoulder in the guide, and with the other end on a shoulder in the tool-holder, serves to retract the tool-holder; the upper end of the tool-holder has an expanded head, fitting loosely in the head of the working cylinder, and receives the blows or strokes of the piston. As the piston rises and falls in the cylinder it closes the ports and incloses a portion of the air between it and the ends of the cylinder, and thus forms an elastic cushion and relieves the operator of the shock of reversing the motion of the piston. The piston is surrounded constantly by a film of air under pressure, and, while not leaking appreciably, seems to sustain little or no wear, notwithstanding the rapid motion. The effect of the rapid and short strokes on cutting tools upon stone, wood, and metal is to produce a smoother surface than has heretofore been practicable with chisels, and with a celerity unapproached by other means. It has a capacity to reach into angles inaccessible to rotative tools." Fig. 1 shows sectional views of the machine, and Fig. 2 its adaptation as a répoussé machine.

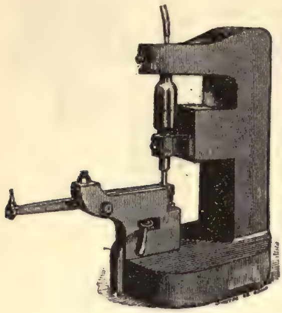


Fig. 2.—Air-tool.

ALARMS, LOW-WATER. Several new alarms for steam-boilers, to give a signal when the water goes below its normal level, have been placed on the market within a few years. Those described below are selected to show the different principles on which they are based:

The Hardwick Automatic Low-Water Alarm, shown in Fig. 1, is explained as follows: When the water gets below the bottom of pipe *F*, the steam rushes up into copper pipe *B*, causing it to expand and raising the bell-crank *H*, blowing the whistle *A*, which will continue to blow until the surface of water *X* raises above the bottom of pipe *F*. There is an opening in lower casting *D*, shown in cut at *E*, connecting the steam space of boiler with iron pipe *C*, connecting with whistle *A*. The advantage of having two pipes and two separate openings in castings *D*, is that the copper pipe *B* having no opening at top will not draw any scum from surface of water *X*, and leaving nothing but clean dry steam in iron pipe *C*. The sounding of the whistle can be stopped by slacking the set screw in lever *H*. The same result can be attained by pouring cold water on the tube *B*, which will quickly contract the tube after the water has reached above the pipe *F*.

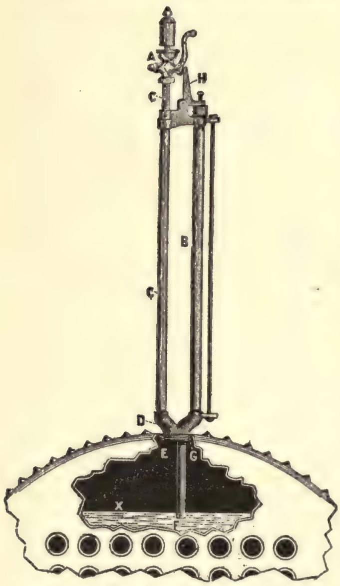


Fig. 1.—Alarm.

The "Reliable" Low-Water Alarm is shown in Fig. 2. It is attached to the boiler at such height that, when the water-level has reached the lowest point which it is to be allowed to fall, the float *G* will be supported so that its lever-arm is just in contact with the valve-rod which admits steam to the whistle.

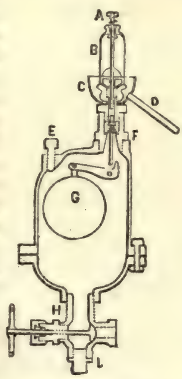


Fig. 2.—Alarm.

ALLOYS. Prof. Thurston's researches on copper-tin and copper-zinc alloys are referred to in Vol. I of this work. His later researches, on the triple alloys of copper, tin, and zinc, have since been published (see Report of the U. S. Board appointed to test Iron, Steel, and other Metals, and *Trans. Am. Soc. Civ. Engrs.*, 1881). The following table is an abstract of the tests in tension made by Prof. Thurston:

Strength and Ductility of Triple Alloys of Copper, Tin, and Zinc.

PERCENTAGE OF			POUNDS STRESS PER SQUARE INCH AT		PER CENT FINAL	
Copper.	Tin.	Zinc.	Elastic limit.	Ultimate resistance.	Stretch.	Contraction.
100	......	......	11,620	19,872	0·05	10
100	......	......	11,000	12,760	0·005	8
100	......	......	14,400	27,800	0·065	15
90	10	......	15,740	26,860	0·037	13·5
80	20	......	......	32,980	0·004	....
70	30	......	5,585	5,585	......	....
62	38	......	688	688	......	....
52	48	......	2,555	2,555	......	....
39	61	......	2,820	2,820	......	....

PERCENTAGE OF			POUNDS STRESS PER SQUARE INCH AT		PER CENT FINAL	
Copper.	Tin.	Zinc.	Elastic limit.	Ultimate resistance.	Stretch.	Contraction.
29	71	......	......	1,684	......	....
21	79	......	......	4,337	......	....
10	90	......	3,500	6,450	0·07	15
......	100	......	1,670	3,500	0·36	75
......	100*	......	......	2,760	......	47
......	100†	......	2,000	3,500	0·36	86
90‡	10‡	......	10,000	31.000	4·6	....
80	.....	20	......	33.140	32·4	40
62·5	......	37·5	......	48.760	31·0	29·5
58·2	2·3	39·5	......	67,600	4·0	8
100	......	......	......	29,200	7·5	16
90·56	......	9·42	......	......	......	....
81·91	......	17·99	10.000	32,670	31·4	43
71·20	......	28·54	9,000	30.510	29·2	38
60·94	......	38·65	16.470	41.065	20·7	28
58·49	......	41·10	27.240	50,450	10·1	17
49·66	......	50·14	16,890	30.990	5	11·5
41·30	......	58·12	3,727	3,727	......	....
32·94	......	66·23	1,774	1,774	......	....
20·81	......	77·63	9,000	9,000	0·16	....
10·30	......	88·88	14.450	14,450	0·39	....
......	......	100	4,050	5,400	0·69	....
70	8·75	20·25	18,000 (?)	31,600	0·36	....
57·50	21·25	21·25	1.300	1,300	......	....
45	23·75	31·25	2.196	2,196	......	....
66·25	23·75	10	3.294	3,294	......	....
58·22	2·30	39·48	30,000 (?)	66,500	3·13	7
10	50	40	5,000 (?)	9,300	0·7	....
60	10	30	21,78C (?)	21,780	0·15	....
65	20	15	......	3,765	......	....
70	10	20	24,000 (?)	33,140	0·31	....
75	5	20	12.000 (?)	34,960	3·2	5·4
80	10	10	12,000 (?)	32,830	1·6	4
55	0·50	44·50	22.000	68.900	9·4	25
60	2·50	37·50	22.000	57,400	4·9	6·6
72·50	7·50	2	11,000	32.700	3·7	11
77·50	12·5	10	20.000	36.000	0·7	....
85	12·5	2·50	12,000 (?)	34,500	1·3	3

* Queensland. † Banca. ‡ Gun-bronze.

The values of the elastic limit in the lower part of the table were not well defined.

Bronzes with High Tensile Strength.—The following table gives the analysis of a number of alloys which have recently come into extensive use. They are described at length by F. Lynwood Garrison in *Journal of the Franklin Institute*, June and July, 1891:

	Tobin bronze.	Tobin bronze.	Damascus bronze.	Phosphor bronze.	Deoxidized bronze.	Aluminum bronze.	Manganese bronze.	Delta metal.
	1	2	3	4	5	6	7	8
Copper	61·20	59	77	79·70	82·67	91·26	88·64	About 60
Zinc	37·44	38·40	......	......	3·23	......	1·57	34 to 44
Tin	0·91	2·16	10·50	10	12·40	......	8·70	1 to 2
Lead	0·18	0·31	12·50	9·50	2·14	0·57	0·30	......
Iron	0·36	0·11	......	......	0·10	0·22	0·72	2 to 4
Aluminum	......	......	......	......	......	7·41	......	......
Manganese	......	......	......	......	......	......	......	......
Silicon	......	......	......	......	......	0·93	......	......
Arsenic	......	......	......	......	......	0·04	.....	......
Phosphorus	......	......	None	0·80	0·005	0·06	Trace	......
	100·09	99·98	100	100	100·545	100·49	99·93	

Nos. 1 and 2. Tobin bronze, claimed to have a tensile strength of 79,600 lbs. per sq. in., elastic limit 54,250 lbs., and elongation 12 to 17 per cent with best rolled bars. No. 3. Damascus bronze, said to wear slower as a bearing metal, than the phosphor bronze. No. 4. No. 4. Phosphor bronze, bearing metal used by the Pa. R. R. Co. No . 5. Deoxidized bronze. Is largely used for wood-pulp digesters, as it is found to resist the action of sodium hyposulphite and sulphurous acid. No. 6. Aluminum bronze, used for firing pins, by the Colts Fire-Arms Co. No. 7. Manganese bronze, used for propellers, cast metal, averages 35,000 to 43,000 lbs. elastic limit, 63,000 to 75,000 lbs. per sq. in., 13 to 22 per cent elongation in 5 in. When rolled the elastic limit is about 80,000 lbs. per sq. in., tensile strength 95,000 to 106,000 lbs., and elongation 12 to 15 per cent. These results have been obtained from manganese bronze made by B. H. Cramp & Co., of Philadelphia. No manganese is present in the alloy, but it may have been used as a flux in casting it. No. 8. Delta metal, formerly known as Sterro metal, and practically the same as Aich's metal. When cast in sand it has a tensile strength of about 45,000 lbs. per sq. in. and about 10 per cent elongation. When rolled a tensile strength of 60,000 to 75,000 lbs., and 9 to 17 per cent elongation. Prof. Thurston's strongest bronze was found to have the composition: copper 55, tin 0·5, zinc 44·5. Tobin's alloy, one of the strongest of the triple alloys contained: copper 58·2, tin 2·3, zinc

39·5. This alloy, like the strongest bronze, is capable of being forged or rolled at a low red heat or worked cold. Rolled hot, its tenacity rose to 79,000 lbs., and when moderately and carefully rolled, to 104,000 lbs.

Silicon Bronze.—This alloy appears to have been invented about the year 1881, by M. Weiller, of Angoulême. In experimenting with phosphor-bronze wire for telegraphic and telephonic use he found its conductivity was insufficient for telegraphic purposes, so he devised the alloy now called silicon bronze. The silicon copper compound, from which the silicon bronze is produced, is made by melting, in a graphite crucible, a certain amount of copper with a mixture of fluor-silicate of potassium, produced glass, chloride of soda, carbonate of soda, and chloride of calcium. It is claimed that the silicon and sodium in this mixture absorb all the oxides present in the mass. The action of the silicon on the copper is similar to that of phosphorus. It acts as deoxidizer, and the silica formed being an acid, is a valuable flux for any metallic oxides remaining unreduced. Wire made from this alloy is said to have the same resistance to rupture as phosphor-bronze wire, but with a much higher degree of electric conductivity. According to Preece, phosphorus has a most injurious influence on the electric conductivity of bronze, and silicon bronze is far superior. It also seems that, although wires made from this alloy are very much lighter than ordinary wires, they are of equal strength. According to E. Van der Ven, phosphor-bronze has about 30 per cent, silicon bronze 70 per cent, and steel 10½ per cent of the electrical conductivity of copper.

Remarkable Aluminum Alloys.—Some recent experiments at Chalais, in France, were made on alloys of the composition given in the following table. The alloys were rolled into sheets 1 mm. thick, and strips 5 mm. in width were cut and tested:

Al, per cent.	Cu, per cent.	Sp. gr. calculated.	Sp. gr. determined.	Tensile strength in pounds per sq. in.
100	..	....	2·67	26,535
98	2	2·78	2·71	43,563
96	4	2·90	2·77	44,130
94	6	3·02	2·82	54,773
92	8	3·14	2·85	50,374

An interesting peculiarity of these alloys is the large divergence between the specific gravities calculated from those of their constituents and the specific gravities directly determined. Each 2 per cent of copper might be expected to raise the specific gravity by 0·12, whereas the actual observed increase is only about 0·05. It will also be observed that the addition of only 2 per cent of copper increases the tensile strength from 26,535 to 43,563 lbs. per sq. in., while 6 per cent more than doubles it. Thus it appears that an alloy of aluminum having double the tensile strength of aluminum itself can be made which is less than one twentieth heavier. The tensile strength and other properties of the Cowles aluminum bronze and brass are shown in the following table, taken from the official report of tests made under the direction of the Engineer-in-Chief of the Navy at the Watertown Arsenal:

Tests made on Specimens of Aluminum Bronze and Brass.

Mark or number.	APPROXIMATE COMPOSITION.	Diameter.	Tensile strength per sq. in.	Elastic limit per sq. in.	Elongation in 15 ins.	Reduction of area.
		Inches.	Lbs.	Lbs.	Per cent.	Per cent.
1 C	Cu 91·5, Al 7·75, Si 0·75	1·875	60,700	18,000	23·20	30·70
7 C	Cu 88·66, Al 10, Si 1·33	1·875	66,000	27,000	8·80	7·80
9 C	Cu 91·5, Al 7·75, Si 0·75	1·875	67,600	24,000	13	21·62
10 C	Cu 90, Al 9, Si 1	1·875	72,830	33,000	2·40	5·78
11 C	Cu 63, Zn 33·33, Al 3¼, Si 0·33	1·875	82,200	60,000 to 73,000	2·33	9·88
13 C	Cu 92, Al 7·5, Si 0·5	1·875	59,100	19,000	15·10	3·592
9 D	Cu 91·5, Al 7·75, Si 0·75	1·900	53,000	19,000	6·20	15·50
10 D	Cu 90, Al 9, Si 1	1·890	69,930	33,000	1·33	3·30
11 D	Cu 63, Zn 33·33, Al 3·33, Si 0·33	1·900	70,400	55,000	0·40	4·33
13 D	Cu 92, Al 7·5, Si 0·5	1·930	46,550	17,000	7·80	19·19

Manganese Bronze.—Mr. Garrison, in the paper above mentioned, says: "For several years past, manganese bronze appears to have been made in large quantities by Mr. P. M. Parsons, of the Manganese Bronze Company, Deptford, England. Dr. Percy was probably the first to observe the action of the manganese in combining with the traces of cupreous oxide of copper present in the copper, deoxidizing the same, and thus making the metal denser and stronger. Mr. Parsons, I believe, adds the manganese in the form of ferro-manganese. A portion of the manganese in the alloy thus added is utilized in the deoxidation above mentioned, while the remainder, together with the iron, becomes permanently combined with the copper. The manganese once alloyed with the copper is not driven off by remelting, but usually the quality of the bronze is improved by a subsequent remelting. The Manganese Bronze Company roll and forge the alloy hot. According to Mr. Parsons, its mean tensile strength as delivered from the rolls is about 67,200 lbs. per sq. in., with an elastic limit of 49,000 to 51,000 lbs. per sq. in., and an elongation of from 23 to 25 per cent. In cold rolling its ultimate tensile strength rises to about 90,000 lbs. per sq. in., with an elastic limit of 67,200 to 76,000 lbs. per sq. in., and an elongation of 10 per cent. If annealed, the ultimate tensile strength is very little altered, but the elastic limit is reduced about half, and the elongation increased to 30 or 35 per cent."

Copper Steel.—Messrs. Schneider & Co., of Creusot, France, have patented a process which consists in making in a blast-furnace, a cupola or a reverberatory furnace, castings containing a variable amount of copper with a less variable proportion of the ordinary elements. These

castings are used for the manufacture of copper steel for armor-plate, ordnance, projectiles, steam cylinders, etc., these articles being hardened or tempered in oil. The copper ore is mixed with the charge in the cupola, or else copper filings can be mixed with the coal to form a copper coke, which is then used in melting the iron in a blast-furnace or cupola. Copper compounds may also be melted in a reverberatory furnace, with a mixture of iron or steel under a layer of anthracite to prevent oxidation. In a paper published in the *Journal of the Iron and Steel Institute*, in 1889, Messrs. E. J. Ball and Arthur Wingham describe some experiments on copper steel made by adding to a very pure basic Bessemer steel varying percentages of an alloy of iron and copper. This alloy was produced by melting pig-iron, and then adding to the molten metal oxide of copper. The carbon and silicon acted as the reducing agents for the cupric oxide, and the copper was thus introduced into the iron by a "reaction," and not by simple solution. A part of the other impurities in the pig-iron was also burned out in this manner, and a metal was obtained which had the following composition:

	Per cent.
Copper	7·550
Carbon	2·720
Manganese	·290
Silicon	·036
Phosphorus	·130
Sulphur	·190

This metal was bright, white in color, crystalline, and very hard, but it did not offer any great resistance to impact. Varying quantities of it were then melted down with the basic Bessemer steel previously mentioned. The products of these fusions were allowed to cool very slowly, the crucibles in which the fusions had taken place being permitted to remain in the furnace until quite cold. Test-pieces, $1 \times \frac{1}{4} \times \frac{3}{16}$ in., were then cut, and submitted to tensile tests in a multiple lever testing machine, the test-pieces being first carefully annealed. In the alloys produced in this manner, the percentages of carbon and of copper necessarily increased simultaneously. The following table shows the percentages of copper and of carbon in the metals tested, and the results of the tensile tests of the various specimens:

TEST-PIECE NUMBER.	Copper, per cent.	Carbon, per cent.	Tensile strength, tons per sq. in.
1	0·847	0·102	18·3
2	2·124	0·217	36·6
3	3·630	0·380	47·6
4	7·171	0·712	56

The total elongation of the test-pieces was also noted, but owing to their small size the results are not trustworthy. The elongations observed, however, were as follows: Test-piece, (1) 10 per cent; (2) 5 per cent; (3) 5 per cent; (4) no visible extension, or the extension was but very slight. The tensile strength of the copper steel is greater than that of steels of like percentage of carbon which contain no copper. Copper also increases the strength of iron and of low carbon steel, as appears from the following results:

DESCRIPTION.	Copper, per cent.	Carbon, per cent.	Tensile strength, tons per sq. in.
Original steel	....	0·133	29
Test-piece 5	4·10	0·183	43·2
Test-piece 6	4·44	Trace	34·3

Mr. F. Lynwood Garrison, in his paper read before the Franklin Institute in 1891, says: "Copper-steel alloys are almost too new to determine for what particular purposes they would be most useful. It is stated in the Schneider patents that they are useful for making ordnance, armor-plate, rifle-barrels, and projectiles, and also for girders for building purposes, and ship-plates. In view of the remarkable elastic limit of copper steel, while maintaining at the same time a very considerable elongation, it would not be surprising if its use became very extensive in the arts. It has the advantage of aluminum, nickel, and tungsten steels, in being cheaper to manufacture. In many of the steel alloys, the alloying metals have to be added to the steel when they are combined with iron, which iron must necessarily contain some carbon—such an increase of carbon in the alloy is nearly always undesirable. Thus, for instance, if the manganese in manganese steel could be added as metallic manganese and not as ferro-manganese (which must contain carbon), we would probably obtain better results with manganese steel. The undesirable increase of carbon in this way is avoided in making copper steel, for as we have seen, the copper can be added in the metallic state, or as an ore."

Alloys for Electrical Conductors.—Mr. Edward Weston has made the remarkable discovery that the metal manganese, besides imparting a very high electrical resistance to alloys into which it enters, as a constituent, has the property of rendering the electrical resistance of such alloys nearly or quite constant under varying conditions of temperature. He therefore uses such alloys for the coils or conductors of electrical measuring instruments. He prefers to use ferro-manganese in the proportion of copper 70 parts and ferro-manganese 30 parts or thereabouts. This, however, is capable of being rolled and drawn, and is made up

Chrome Steel.

NUMBER.	OBSERVER, SOURCE, ETC.	COMPOSITION. Chromium.	Combined carbon.	Graphite.	Manganese.	Silicon.	Tungsten.	PHYSICAL PROPERTIES. Tensile strength, lbs. per sq. in.	Elastic limit, lbs. per sq. in.	Elongation. Per cent.	Elongation. Inches.	Reduction of area per cent.
1	Unieux, unhardened, Brustlein	4	1·10	...	...	...	...	177,800	...	7·5	...	...
2	" "	2·2	0·6	...	...	...	...	103,000	67,500	19	...	67·+
5	A. A. Blair and D. Smith, P.	0·45 @ 0·92	0·84 @ 1·19	0·01 @ 0·03	0·03	1·28	...	115,922	...	...	...	...
6	" " F.	0·22 @ 0·64	0·81 @ 0·99	0·01 @ 0·92	...	...	...	104,756	...	...	...	...
7	Brooklyn Adamantine, Hunt and Clapp and Howe	0·53	1·03	...	0·17	0·05	...	157,000	...	0·6	4″	...
								116,000	...	0·6	4″	...
9	Brooklyn, very hard, Hunt and Clapp and Howe	0·38	0·90	...	1·89	0·03	0·98	134,000	...	2	4″	...
9·5	A. A. Blair and D. Smith, G.	0·38	0·84	0·01	0·22	0·09	...	110,572	...	...	...	...
12	Brooklyn, Hunt and Clapp and Howe	0·29	1·32	...	0·15	0·15	0·73	124,000	...	6	3·5″	4
								127,000	...	9	3·5″	2
13	Brooklyn 1A, Hunt and Clapp and Howe	0·25	0·70	...	...	...	...	145,400	...	5·5	...	19
16	Unieux, unhardened, (same bar, Barbier, Boussingault.)	...	...	...	...	...	...	108,700	85,446	15	...	50
17	" quenched from yellow, (same bar, Barbier, Boussingault.)	...	...	...	...	...	...	191,000	...	1·2	...	2
18	" " bright cherry, (same bar, Barbier, Boussingault.)	...	...	...	...	...	...	202,900	...	2	...	6
19	" " cherry, (same bar, Barbier, Boussingault.)	...	...	...	...	...	...	104,260	62,306	14	...	63
20	" " dark red, (same bar, Barbier, Boussingault.)	...	...	...	...	...	...	100,000	55,000	17	...	63

into wire in the usual way. He has also discovered another alloy, the resistance of which is lowered by an increase of temperature, and he utilizes the same in making coils, etc., for such electrical instruments as should have a constant resistance under variable temperature, by making one part of the coil of said alloy and the other portion of German silver, or some other of the ordinary metals. In such case, the resultant resistance is constant, provided the change in the two parts of the coil be equal as well as opposite. This alloy preferably consists of 65 to 70 parts of copper, 25 to 30 parts of ferro-manganese, and 2½ to 10 parts of nickel.

Ferro-chrome and Chrome Steel.—M. Brustlein, of Holtzer & Co.'s steel works in the Loire, France, read a paper before the International Congress of Mines and Metallurgy, in Paris, in 1889, on ferro-chrome and chrome steel, from which we extract the following:

"There may be introduced into steel varying proportions of chromium of which the effect is to increase the resistance of steel without diminishing the tenacity corresponding to its carbon contents, and even, it appears, to slightly increase that tenacity. In consequence, it is possible to obtain, with a resistance given to the rupture, a bending corresponding to that which is obtained with a steel that is ordinarily less resisting or softer; that is to say, in describing it, as a metal which, well handled, offers a very great security. At the forge, an ingot of chrome steel may be worked with no more difficulty than with ordinary steel of the same hardness; nevertheless, when hot, it offers a greater resistance to deformation. When an ingot is cut hot by a cutter, the metal is more ductile; the point of contact between the two pieces is flattened out into a thin web before breaking. It is influenced by the fire even less than an ordinary steel of the same hardness. In the cold, when worked on a lathe or with a plane, a steel containing, for instance, 2 per cent of chromium is always a little harder to cut than ordinary steel; nevertheless, if it is properly reheated the difference is not great. Steel that contains less chromium, even when it has 1 per cent carbon, may be worked without difficulty on a lathe. Tempered with oil or with water, the temper penetrates more deeply than in a carbonized steel of the same degree of carbonization without chromium. Chrome steel offers a resistance to shock and to fracture which, for the time being, makes it preferable for a certain number of uses. On the other hand, when once made into ingots, it can be manipulated like ordinary steel, which is an additional advantage. But it offers in its manufacture difficulties of a special nature. In a state of fusion, which takes place at high temperatures, the chromium which it contains has a tendency to take up oxygen from the air. In such case there is not formed, as is the case with oxide of manganese, a liquid and fusible silicate lighter than steel, which comes rapidly to the surface, but instead there is caused the decarbonization of the steel and the oxidation of the iron, giving rise to a creamy layer, of which the little fragments rest readily, not only on the edges of the casting-pot, but even in the mass of the metal. The portions thus oxidized will not unite under any working, no matter to what temperature they may be heated. For

the same reason, the layer of oxide which is formed on heating the ingots or bars is stronger and adheres closer than in ordinary steel, and does not easily dissolve in borax. Also, chrome steel only unites with difficulty or not at all, according to the amount of chromium it contains. For these reasons chrome steel will require most delicate treatment, and it will be exceedingly difficult to use it in the manufacture of sheeting."

The accompanying table (page 26), showing analyses and physical properties of several samples of chrome steel, is abridged from a table in Howe's *Metallurgy of Steel:*

Nickel Steel.—Steel containing a small per centage of nickel has recently been found to possess the valuable property of increased tensile strength and hardness, as compared with ordinary steel of the same carbon percentage, without the decrease of ductility which in carbon steel accompanies increase of tensile strength. It has been found to be especially valuable for armor-plate, as shown by experiments made at the Annapolis proving-ground, and also in Europe in 1890 and 1891 (see *Trans. U. S. Naval Institute*, 1891). The manufacture and properties of nickel steel are thus described in a paper by Mr. James Riley, of Glasgow, published in the *Journal of the Iron and Steel Institute*, May, 1889: "The alloy can be made in any good open-hearth furnace working at a fairly good heat. The charge can be made in as short a time as an ordinary 'scrap' charge of steel—say, about 7 hours. Its working demands no extraordinary care; in fact, not so much as is required in working many other kinds of charges, the composition of the resulting steel being easily and definitely controlled. If the charge is properly worked nearly all the nickel will be found in the steel —almost none is lost in the slag, in this respect being widely different from charges of chrome steel. The steel is steady in the mold, it is more fluid and thinner than ordinary steel, it sets more rapidly, and appears to be thoroughly homogeneous. The ingots are clean and smooth in appearance on the outside, but those richest in nickel are a little more 'piped' than are ingots of ordinary mild steel. There is less liquation of the metalloids in these ingots, therefore liability to serious troubles from this cause is much reduced. Any scrap produced in the subsequent operations of hammering, rolling, shearing, etc., can be remelted in making another charge without loss of nickel. No extraordinary care is required when reheating the ingots for hammering or rolling. They will stand quite as much heat as ingots having equal contents of carbon but no nickel, except, perhaps, in the case of steel containing over 25 per cent of nickel, when the heat should be kept a little lower and more care taken in forging. If the steel has been properly made, and is of correct composition, it will hammer and roll well, whether it contains little or much nickel; but it is possible to make it of such poor quality in other respects that it will crack badly in working, as is the case with ordinary steel. In endeavoring to obtain a correct idea of the value or usefulness of alloys of nickel and iron or steel, we shall find it of use to consider their behavior under tensile and other mechanical tests, and if these were

Tests of Steel with varying Contents of Nickel.

MARK.	COMPOSITION PER CENT.			TENSILE STRENGTH AS CAST.					TENSILE TESTS AS CAST AND ANNEALED.					TENSILE TESTS AS ROLLED.					TENSILE TESTS AS ROLLED AND ANNEALED.					REMARKS.
	Ni.	C.	Mn.	E. L.	B. S.	Extension per cent in		C. A.	E. L.	B. S.	Extension per cent in		C. A.	E. L.	B. S.	Extension per cent in		C. A.	E. L.	B. S.	Extension per cent in		C. A.	
						8 in.	4 in.				8 in.	4 in.				8 in.	4 in.				8 in.	4 in.		
	Per ct.	Per ct.	Per ct.	Tons.	Tons.			Per ct.	Tons.	Tons.			Per ct.	Tons.	Tons.			Per ct.	Tons.	Tons.			Per ct.	
1	1	0·42	0·58	Test-piece defective.					27·3	54·6	....	1·5	9·5	32·1	57·6	....	11	24	30·1	55·1	....	18·7	45	
2	2	0·90	0·50	Too hard to machine with musket-steel. Makes a fine tool tempered at dull red in boiling water.																				
3	3	0·35	0·57	19·8	34·9	....	2·5	5·6	24	34·9	....	2·5	9	31·4	51	....	20.3	37	28	48·5	....	20·8	42	
4	3	0·60	0·26	....	....	....	....	....	....	....	....	....	....	29·4	51·5	9	10·1	9	30·3	42·9	7·5	9	12	
5	4	0·85	0·50	Too hard to machine with musket-steel. Makes a fine tool tempered at dull red in boiling water.																				
6	4·7	0·22	0·23	....	....	....	....	....	....	....	....	....	....	25·1	40·5	17·75	23·4	42	28	40·6	20	25	44·8	Average reduced by one piece, giving low result.
7	5	0·30	0·30	....	....	....	....	....	....	....	....	....	....	30	46·4	10	12·5	22·5	28	42·6	15	17·5	18·5	
8	5	0·50	0·34	....	....	....	....	....	....	....	....	....	....	31·1	52	14	15·6	14	32·5	46·8	13·5	14	17	
9	10	0·50	0·50	Too hard to machine. Makes a good cutting tool when tempered in cold air-blast.																				
10	25	0·27	0·85	....	....	....	....	....	....	....	....	....	....	38·2	51·4	10·5	11·7	....	12·75	45·8	29	30	28·6	
11	25	0·82	0·52	....	....	....	....	....	....	....	....	....	....	22	47·6	43·5	47·6	60	15·1	42·1	40	45·3	43·6	
12	49·4	0·35	0·57	....	....	....	....	....	....	....	....	....	....	20·5	37·4	....	12	24	21	37	....	20	29	

E. L. = Elastic limit. B. S. = Breaking strain. C. A. = Contraction of area.

sufficiently numerous, our task would not be a very difficult one. If it be remembered, however, that in the composition of nickel steel we have present nickel and manganese and iron, with carbon, silicon, sulphur, and phosphorus, and that even a very small difference in the contents of some of these has a considerable influence on the character of the alloy, it will be evident that several series of tests (involving a very large number of separate experiments) are necessary to a full investigation. For instance, we all know the effect of very small increments of carbon in steel; hence to estimate correctly, the influence of the addition of nickel, the carbon (as well as manganese and other contents) should remain constant; then that contents of nickel should be constant and the carbon, etc., varied; further, that the subsequent treatment of all the products should be identical in every particular."

In the table given on page 27 there are several points of interest which it is desirable to notice.

1. In No. 6 test the carbon present (0·22) is low enough to enable us to make comparison with ordinary mild steel, which would give (when annealed) results about as follows: E. L. 16 tons, B. S. 30 tons, extension 23 per cent on 8 in., and contraction of area 48 per cent. Therefore in this case the addition of 4·7 per cent of nickel has raised E. L. from 16 to 28 tons, and the B. S. from 30 up to 40·6 tons, without impairing the elongation or contraction of area to any noticeable extent. In No. 3 test somewhat similar results are found, with an addition of only 3 per cent of nickel, combined with an increase of the carbon to 0·35 per cent.

2. In Nos. 2 and 5 tests there is extreme hardness, due in part to the large quantity of carbon present, but also to the presence of nickel in addition. In No. 9 test, with the carbon very much reduced, this characteristic of hardness is intensified by the increase of nickel to 10 per cent. This quality of hardness obtains as the nickel is increased, until about 20 per cent is reached. when a change takes place, and successive additions of nickel tend to make the steel softer and more ductile, and even to neutralize the influence of carbon, as is shown in No. 11 test, in which there is 25 per cent of nickel and 0·82 per cent of carbon.

3. In the 25-per-cent nickel steel there are some peculiar and remarkable properties. In the unannealed specimen the B. S. is high and the E. L. moderately so; but in the annealed piece, in which the B. S. remains good, the E. L. is very greatly reduced, down to one third of the B. S. Again, in both cases, the ductility as shown by the extension before fracture is marvelous, reaching 40 per cent in 8 in.

There are a few other properties of these alloys which may be noticed. The specific gravity of nickel is given as 8·66 to 8·86; that of ferro-nickel, if 25 per cent nickel, 8·08; that of 10-per-cent nickel, 7·866; that of 5-per-cent nickel, 7·846; while the mean of results of hammered steel is 7·84. The whole of the series of nickel steels up to 50 per cent nickel take a good polish and finish, with a good surface, the color being lighter with the increased additions of nickel. The steels rich in nickel are practically non-corrodible, and those poor in nickel are much better than other steels in this respect. Thus, some experiments we have made show that, as compared with mild steel of 0·18 carbon, 5-per-cent nickel steel corrodes in the ratio of 10 to 12, and, as compared with steel having 0·40 carbon, with 1·6 chromium, in that of 10 to 15. In the case of 25-per-cent nickel steel, these ratios are as 10 is to 870, and 10 to 1,160, respectively. These results were obtained by immersion of samples of the different steels in Abel's corrosive liquid, and the results confirmed by subsequent immersion in water acidified by hydrochloric acid. Some samples of the richer nickel steels which have been lying exposed to the atmosphere for several weeks still show an untarnished fracture. The alloys up to 5 per cent of nickel can be machined with moderate ease; beyond that strength they are more difficult to machine. The poorer ones stand punching exceedingly well, both as rolled and after annealing. The punch-holes can be put as close together as ¼ in. without the metal showing any signs of cracking. The 1-per-cent nickel steel welds fairly well, but this quality deteriorates with each addition of nickel. The poorer alloys do not show any luster, but the richer ones have a lustrous appearance when the scale is removed. See ARMOR.

ALUMINUM or **ALUMINIUM.** Webster and Worcester sanction either way of spelling—Webster giving "aluminum" as preferable, Worcester "aluminium." German, alumium; French, aluminium. In England, aluminium has the preference. In America, aluminum is most used, and the shorter name *alium* is being strongly urged in preference to either. Chemical symbol, Al. Atomic weight, 27·02. Aluminum group, aluminum, indium, gallium. These metals form feebly basic sesquioxides, which act toward stronger bases as acid-forming oxides.

Occurrence of Aluminum in Nature.—Of all the elements aluminum is the most widely distributed and contained in the largest quantity in the solid crust of the earth, except oxygen and silicon. Its ores from which pure alumina is obtained, from which the pure metal is extracted, are: Bauxite ($Al_2H_6O_6$), soft and granular, with 50 to 70 per cent of oxide of aluminum, and with only a few per cent of accidental impurities besides the water of hydration. Corundum (Al_2O_3), very hard and crystalline, specific gravity 3·909, with 93 per cent alumina, and ordinarily very free from impurities, but so hard and crystalline, and withal so valuable for other purposes, as not to be at present used as an aluminum ore. Diaspore ($Al_2O_3H_2O$), hard and crystalline; specific gravity 3·4, with 65 to 85 per cent alumina, and ordinarily very pure. Cryolite (Al_2Fl_66NaFl), specific gravity 2·9, with 40 per cent aluminum fluoride and 60 per cent sodium fluoride. Aluminite ($Al_2SO_69H_2O$), specific gravity 1·66, containing some 30 per cent of alumina in a condition, by roasting, solution, and filtration, to be cheaply purified. Gibbsite ($Al_2O_33H_2O$), stalactitic; specific gravity 2·4, containing 65 per cent alumina. The oxide of aluminum occurs largely in combination with

silica, chiefly as double silicates, of which orthoclase or potash feldspar ($K_2Al_2SiO_6$) is most important, forming the chief constituents of granite, gneiss, syenite, porphyry, trachyte, etc. Soda feldspars and lime feldspars also occur in the large garnet and mica groups of minerals, both double silicates of aluminum. Weathering of feldspars has formed the clays which are silicates of aluminum. Neither feldspars or clays, however, are economical ores, in comparison with those given above, for the production of aluminum, on account of the difficulty of separation from the silica. Aluminum is shown by the spectroscope as being present in the solar atmosphere.

Chemical Properties.—Aluminum-leaf decomposes water at 100°, and, heated in oxygen gas, burns with an intense white flame. The resulting compound, however, shows the metal not to have been completely burned to an oxide, but to have been protected by a surface coating. The metal dissolves in aqueous solutions of alkalies; with the evolution of hydrogen, deposits lead, silver, and zinc from alkaline solutions, while neutral or acid solutions are not altered by it. It precipitates copper from a solution of sulphate of copper. Hydrochloric acid is its best solvent. Concentrated sulphuric acid dissolves aluminum on heating, with evolution of sulphurous acid, dilute sulphuric acid acting only very slowly on the metal. The presence of any chlorides in the solution, however, allows it to be rapidly decomposed. Nitric acid, either concentrated or dilute, has very little action on aluminum. Organic acids attack the metal only slightly. Sulphur has no action on it at a temperature less than a red-heat. Aluminum is not acted upon by carbonic acid or carbonic oxide gases, nor sulphureted hydrogen, but it is a peculiarity of the metal in a melted condition to absorb large quantities of these gases, a portion of which is again excluded on the metal cooling, but enough being left, in the case of sulphureted hydrogen, to continue to emit a strong odor for a long time after solidifying. Aluminum is little acted upon by salt water; and even solutions of salt and vinegar, such as the metal is likely to be subjected to in certain culinary operations, do not seem to practically injure the metal. It is less acted upon than tin, copper, or silver under similar conditions. Aluminum is found to withstand the actions of organic secretions better than even silver, and it is largely used for surgical and dental instruments. Solutions of caustic alkalies, chlorine, bromine, iodine, and fluorine, rapidly corrode aluminum. Ammonia gas has very little action upon the metal except to turn it to a gray color. Strong aqua-ammonia has a slight solvent action upon it. Pure aluminum does not tarnish from the influence of the weather, except very slowly, even though the atmosphere be moist or even salt. Instead of retaking oxygen, like the metals of the alkalies and alkaline earths, with an energy proportioned to the extreme difficulty with which it departs from its oxygen in the state of oxide, aluminum is almost as indifferent to oxygen as are gold and platinum. The strong affinity of aluminum and oxygen before separation, contrasted with their apparent total indifference afterward, may be explained by the existence of a thin film of oxide, which almost immediately forms upon the exposure of the metal to the atmosphere, and protects it from further oxidation. The resistance of aluminum to atmospheric influences, and its anti-corrodibility, are among its most noted qualities. The presence of silicon in aluminum materially detracts from its power to withstand corrosion. Aluminum containing sodium is rapidly acted upon by hot water, the sodium being eaten out, leaving the aluminum spongy and porous. Aluminum or aluminum compounds do not impart any color to the non-luminous gas-flame. The spark-spectrum of aluminum has been mapped, and contains a large number of bright lines lying close together, of which the most important in the red are 6,423 and 6,425, and in the blue 4,661 and 4,662; and the aluminum bands seen in the ultra-violet are extremely characteristic. Heated in an atmosphere of chlorine gas, aluminum burns violently to a chloride. Aluminum melts at a temperature between silver and zinc—a temperature of 700° C. (authority, Roscoe); 1,300° F. (authority, Richards). The metal becomes pasty at about 1,000° F., and loses its tensile strength and very much of its rigidity at a temperature between 400° and 500° F., although this rigidity and strength are almost entirely regained as the metal cools. Aluminum does not volatilize at any temperature ordinarily to be produced by the combustion of carbon, even though the high temperature be kept up for a considerable number of hours' time. It, however, absorbs a very large amount of occluded gases by such treatment. The impurities most commonly found in aluminum are silicon and iron; and it may be said of the electrolytically made metal that these two impurities are almost the only ones found, considerable amounts of any others being accidental. A large proportion of the aluminum being made by the newer electrolytic processes, runs over 99 per cent pure aluminum, the impurities coming simply from the alumina ore and the ash of the carbon electrodes, the impurities in the reagent solvents for the alumina being reduced and alloyed with the first metal made. Silicon in aluminum exists in two forms, one seemingly combined with the aluminum as combined carbon exists in pig-iron, and the other in an allotropic graphitoidal modification. These two forms of the silicon seem to exert considerably different effects by their presence in the aluminum, the combined form of the element rendering the metal much harder than the graphitoidal variety. The combined modification ordinarily preponderates, and is usually from 55 to 80 per cent of the total silicon. The presence of iron as an impurity in aluminum is more easily avoided, and, by taking care in the use of tools and that the grinding of the carbon is done with good stone wheels, its presence is very often a mere trace. For many purposes the purest aluminum can not be so advantageously used as that containing from 3 to 6 per cent impurities, as the pure metal is very soft, and not so strong as the less pure. It is only where extreme malleability, ductility, or non-corrodibility is required that the purest metal should be used. For most purposes small amounts of some of the other metals than silicon and iron are advantageously added, to produce

hardness, rigidity, and strength—constituents that will not detract from the non-corrodibility of the metal as much as do these natural impurities that come from the ore and apparatus.

Physical Properties.—Pure aluminum is white in color, with a decided bluish tint, which becomes very much more marked upon exposure, when the thin film of white oxide on its surface prevents further tarnishing from the air, but which seems to give it, by contrast to the metal as a background, an enhanced bluish tint. The addition of small percentages of silver, chromium, manganese, tungsten, or titanium changes the color of aluminum, rendering it nearer that of silver, as well as considerably increasing the hardness and stiffness of the metal. Pure aluminum has no taste or odor. Under heat, the coefficient of linear expansion of ⅜ in. round aluminum rods of 98½ per cent purity is ·0000206 per degree C., between the freezing and boiling points of water; that of iron being ·0000122; tin, ·0000217; copper, ·00001718 (authorities, Hunt, Langley, and Hall). Sound castings of aluminum can readily be made in dry sand molds, if the metal is not heated much beyond the melting-point, to prevent the absorption of gases. The metal does not need any flux. Its shrinkage is $\frac{17}{64}$ in. to the foot. The mean specific heat of aluminum from 0° to the melting-point is 0·285, water being taken as one, and the latent heat of fusion is 28·5 heat-units (authority, Richards). The coefficient of thermal conductivity of aluminum, obtained by the method of Wiederman and Franz, silver being taken as 100 and copper as 73·6, is for unannealed aluminum 37·96, for annealed aluminum 38·87. Aluminum stands fourth, being preceded only by silver, copper, and gold, as a conductor of both heat and electricity. One yard of annealed aluminum wire of 98½ per cent purity, ·0325 in. diameter, 14° C., has ·05484 of an ohm resistance, a yard of pure copper wire having a resistance of ·0315. The electrical conductivity of silver being taken at 100, copper as 90, pure annealed aluminum has an electrical conductivity of about 50. Pure aluminum has no polarity, and indeed the commercial metal in the market is practically non-magnetic. Pure aluminum is very sonorous, and its tone seems to be improved by alloying with a few per cent of silver or titanium. Pure aluminum is, when properly treated, a very malleable and ductile metal. It can readily be rolled into sheets ·0005 in. thick, or be beaten into leaf nearly as thin as gold-leaf, or be drawn into the finest wire. Pure aluminum stands third in the order of malleability, being exceeded only by gold and silver, and in the order of ductility seventh, being exceeded by gold, silver, platinum, iron, softest steel, and copper. Both its malleability and ductility are greatly impaired by the presence of the two common impurities, silicon and iron. Aluminum can be rolled or hammered cold, but the metal is most malleable at, and should be heated to, between 200° and 300° F., for rolling or breaking down from the ingot to the best advantage. Like silver and gold, aluminum has to be frequently annealed, as it hardens remarkably upon working. By reason of this phenomenon of hardening during rolling, forging, stamping, or drawing, the metal may be turned out very rigid in finished shape, so that it will answer excellently well for purposes where the annealed metal would be entirely too soft or too weak or lacking in rigidity. Especially is this true with aluminum alloyed with a few per cent of titanium, copper, or silicon. The alloys do not show their increased hardness to anything like its maximum extent in castings—not at all in proportion to the increased brittleness. But when these castings are drop-forged, rolled, hammered or drawn down, with only sufficient annealings to prevent the metal from cracking, the increased hardness appears in a remarkable degree. It can be safely stated, as a general rule, that the purer the aluminum the softer and less rigid it is. The fracture of impure aluminum shows ordinarily hexagonal crystals, although the pure metal is very tough, and on breaking, by bending backward and forward, often appears distinctly fibrous and silky in fracture.

Annealing Aluminum.—To anneal aluminum a low and even temperature should be maintained in the muffle—just such a temperature as will show an even red-heat in a piece of iron or steel placed in the muffle, when viewed at twilight or on a dark day. The aluminum itself, however, should not appear at all red at this temperature. A ready test of this is that the metal has been heated enough to char the end of a pine stick, which will leave a black mark on the plate as it is drawn across it. When the metal has acquired this temperature it should be taken from the furnace and allowed to cool gradually. Very thin sections may be annealed by placing them in boiling water, and either allowing them to cool with the water or taking them out to cool gradually. It is possible to anneal to any degree, by lowering the temperature to which the metal is heated below that specified by means of suitable appliances. Aluminum wire alloyed with a few per cent of copper, titanium, or silver, can be drawn, having a tensile strength of 80,000 lbs. to the sq. in., and which will have, weight for weight with copper wire, an electrical conductivity of 170, that of copper being 100. When it is taken into consideration that the copper has a tensile strength at a maximum of 30,000 lbs. to the sq. in., against 80,000 lbs. per sq. in. for aluminum titanium alloy, and that iron and soft steel wire have each a conductivity of 12 in the same scale, and at most a strength equal to that of the aluminum-titanium alloy, a wide field for usefulness as electrical conductors seems open for aluminum. Aluminum can be easily welded electrically, and solders satisfactorily. The specific gravity of aluminum is one of its most striking properties, it being from 2·56 to 2·70; structural steel being 2·95, copper 3·60, ordinary high brass 3·45, nickel 3·50, silver 4, lead 4·8, gold 7·7, platinum 8·6 times heavier. A cub. in. of aluminum weighs ·092 lbs., or 1½ oz. avoirdupois. Cast aluminum has about the ultimate strength of cast-iron in tension, but under compression it is comparatively weak. The following is a table of average tensile and compression strength of the metal, the average of many results of tests of the metal of 98 per cent purity:

	Pounds.
Elastic limit per sq. in. in tension (castings)	6,500
" " " " (sheet)	12,000
" " " " (wire)	16,000–30,000
" " " " (bars)	14,000
Ultimate strength per sq. in. in tension (castings)	15,000
" " " " " (sheet)	24,000
" " " " " (wire)	30,000–65,000
" " " " " (bars)	28,000
Percentage of reduction of area in tension (castings)	15 per cent
" " " " (sheet)	35 "
" " " " (wire)	60 "
" " " " (bars)	40 "
Elastic limit per sq. in. under compression in cylinders, with length twice the diameter	3,500
Ultimate strength per sq. in. under compression in cylinders, with length twice the diameter	12,000

The modulus of elasticity of cast aluminum is about 11,000,000.

Under transverse tests pure aluminum is not very rigid. A 1 in. square bar of good cast-iron supported on knife-edges 4 ft. 6 in. long and loaded in the center will readily stand 500 lbs. without a deflection of over 2 in. A similar bar of aluminum would deflect over 2 in. with a weight of 250 lbs., although the aluminum bar would bend nearly double before breaking, while the cast-iron will ordinarily break before the deflection has gone very much beyond 2 in. Aluminum and copper form two series of valuable alloys, the aluminum bronzes ranging from 2 to 12 per cent of aluminum with copper, the copper-hardened aluminum series with from 2 to perhaps 20 per cent of copper with the aluminum. In the 5 to 12 per cent aluminum bronzes we obtain some of the densest, finest-grained, and strongest metals known—metals having remarkable ductility as compared with tensile strength. A 10-per-cent bronze can readily and uniformly be made in forged bars, with 100,000 lbs. per sq. in. tensile strength, with 60,000 lbs. elastic limit per sq. in., and with at least 10 per cent elongation in 8 in.; and aluminum bronzes can be made to fill a specification of even 130,000 lbs. per sq. in., and 5 per cent elongation in 8 in. Such bronzes have a specific gravity of about 7·50, and are of a light-yellow color. The 5 to 7½ per cent aluminum bronzes of from 8·30 to 8 specific gravity, and a handsome yellow color, readily give 70,000 to 80,000 lbs. per sq. in. tensile strength, with over 30 per cent elongation in 8 in., and with an elastic limit of over 40,000 lbs. per sq. in. It will probably be alloys of the latter characteristics that will be most used—especially for marine work; and the fact that 5 to 7 per cent bronzes can be rolled or hammered at a red-heat, proper precautions, which can readily be secured, being taken, will greatly enlarge their use. Metal of this character can be worked in almost every way that steel can, and has the advantages of greater strength and ductility, and greater ability to withstand corrosion. The presence of silicon makes a harder bronze, but one of much less comparative ductility and a less malleable alloy. The presence of iron weakens, and very seriously interferes with the value of the bronze. The presence of zinc in aluminum bronze is not so deleterious—in fact, it makes the best aluminum brasses, much better than those having tin in them. Aluminum in bronzes lowers the melting-point of the copper at least 100° or 200°. The melting-point of 10 per cent aluminum bronze is somewhere in the neighborhood of 1,700° F. Aluminum bronze is among the hardest of the bronzes, and hardens upon cold working considerably. This hardness, however, can be lowered by annealing at a red-heat and plunging into cold water. Aluminum bronze can readily be tooled in a lathe, and the chips being cut clean and smooth and long do not clog the tool. Aluminum bronze is a remarkably rigid metal under transverse strain, being much more rigid than ordinary brass or even gun bronze; and under compression strain, although rather low in elastic limit compared with its ultimate compressive strength, it is still much stronger than any of the other bronzes. It undergoes a long period of gradual compression before it finally gives way, making it peculiarly a safe metal under compressive strain. Aluminum bronze has special anti-friction qualities, owing to its fine grain texture and peculiarly smooth and unctuous though hard surface, which resists abrasion remarkably. Attention has already been called to the anti-corrosive qualities of aluminum bronze, and, as its electrical conductivity is better than that of brass, it is especially well adapted for parts of electrical machinery. Aluminum bronze can be brazed and soldered nearly as well as brass. Sound, clean castings of aluminum bronze can be safely and regularly made, either in sand molds or against chills, if the proper precautions are taken to avoid: 1. Oxidation. 2. Contamination from scum, or a cinder composed of oxide of aluminum with a little copper in it. 3. Contraction cracks, caused by strains due to shrinkage. 4. The shutting in of gas into the castings. The first trouble—oxidation—can be prevented by not heating the metal too hot in the plumbago crucibles. The second trouble—contamination from scum—can be avoided by pouring into a hot ladle or pouring-basin large enough to hold all the metal necessary to fill the mold, and permitting the metal to escape from the bottom of this receptacle, after giving sufficient time to allow the scum to come to the surface. Proper skim-gates should also be provided for each mold. The third difficulty—contraction—is overcome by giving plenty of allowance of metal to feed the casting in cooling. This can be done in several ways, each best adapted for varying conditions. The cores should be made of a yield-

ing character, using resin or other suitable substance, with coarse sand, that will yield under slight pressure. Unyielding iron metal cores should be dispensed with as far as possible. Castings should have "risers" or "feeding-heads" with flaring openings large in section—even larger than the castings they are intended to feed. The feeding-heads should be refilled as often as they will take the metal. In this way the castings are solidified first, drawing the metal to supply their shrinkage from the still fluid "riser," having a level higher than the casting itself. The gates to the mold should be of sufficient number and so arranged that they can be filled with metal as cold as it will pour and give full castings. The fourth difficulty—gas in the castings—can be prevented by taking the ordinary precautions used by founders for this purpose.

Alloys with Small Percentages of Copper.—The alloys of aluminum with copper in proportions of from 2 to 15 per cent have been advantageously used to harden aluminum in cases where a more rigid metal is required than pure aluminum. Copper is the most common metal used at present to harden aluminum. A few per cent of copper decreases the shrinkage of the metal, and gives alloys that are especially adapted for art castings. The remainder of the range, from 20 per cent copper up to over 85 per cent, give crystalline and brittle alloys of no use in the arts, which are of a grayish-white color up to 80 per cent copper, where the distinctly yellow color of the copper begins to show itself.

Aluminum with Iron and Steel.—Aluminum combines with iron in all proportions. None of the alloys, however, have proved of value, except those of small percentages of aluminum with steel, cast-iron, and wrought-iron. So far as experiments have yet gone, other elements can better be employed to harden aluminum than iron, the presence of which in metallic aluminum is regarded as entirely a deleterious impurity, to be avoided if possible. It has been experimentally proved that the addition of aluminum to the steel just before "teeming" causes the metal to lie quiet and give off no appreciable quantity of gases, producing ingots with much sounder tops. There are two theories to account for this: one, that the aluminum decomposes these gases and absorbs the oxygen contained in them; the other is, that aluminum greatly increases the solubility in the steel of the gases which are usually given off at the moment of setting, thus forming blow-holes and bubbles. This latter theory is the one which at present has the greatest weight of authority. In all cases the aluminum should be thrown into the ladle after a small quantity of the steel has already entered it. There is danger of adding too large a quantity of aluminum, in that the metal will set very solid and will be liable to form deep "pipes" in the ingots. To add just the right proportion of aluminum requires some little experience on the part of the steel manufacturer, but successful results have been secured with from ¼ to ¾ lbs. of aluminum to a ton of steel. If the metal be "wild" in the ladle, full of occluded gases, too hot, or oxidized, a larger proportion of aluminum can be advantageously added. R. A. Hadfield says that the influence of aluminum appears to be like that of silicon, though acting more powerfully. The same writer, together with H. M. Howe and Osmund, claims that an addition of aluminum does not lower the melting-point of the steel. Steel with an addition of one tenth of one per cent of aluminum seems to solidify in the molds fully as quickly as steel without the addition of the aluminum. Aluminum seems to take the oxygen out of steel very much in the same way that manganese does. The addition of aluminum in quantities of from 2 to 3 lbs. per ton is of advantage where the steel is to be cast in heavy ingots which will receive only scant work. Here it seems to increase the ductility as measured by the elongation and reduction of area of tensile test specimens, without materially altering the ultimate strength. In steel castings the benefit from the use of a small percentage of aluminum, ordinarily in the proportion of from 2 to 3. lbs per ton, has become widely recognized, and it is being generally used. The additions of aluminum are most always made by throwing the metal in pieces weighing a few ounces each into the ladle as the steel is pouring into it. In cast-iron, from 2 to 5 lbs. of aluminum per ton is put into the metal as it is being poured from the cupola or melting-furnace. To sott gray No. 1 foundry iron it is doubtful if the metal does much good, except, perhaps, in the way of keeping the iron melted for a longer time; but where difficult castings are to be made, where much loss is occasioned by defective castings, or where the iron will not flow well or give sound and strong castings, the aluminum certainly in many cases allows of better work being done and stronger and sounder castings being made, having a closer grain, and hence much easier tooled. The tendency of the aluminum is to change combined carbon to graphitic, and it lessens the tendency of the metal to chill. Aluminum in proportions of two per cent and over materially decreases the shrinkage of cast-iron. The effect of aluminum in wrought-iron is not very marked in the ordinary puddling process. It seems to add somewhat to the strength of the iron, but the amount is not of sufficient value to induce the general use of aluminum for this purpose. The peculiar property of aluminum in reducing the long range of temperature between that at which wrought-iron first softens and that at which it becomes fluid, is taken advantage of in the well-known Mitis process for making "wrought-iron castings." It is for this that aluminum is most used in wrought-iron at present.

Aluminum and other Metals.—With the exception of lead, antimony, and mercury, aluminum unites readily with all metals, and many useful alloys of aluminum with other metals have been discovered within the last few years. The useful alloys of aluminum so far discovered are all in two groups, the one of aluminum with not more than 15 per cent of other metals, and the other of metals containing not over 15 per cent of aluminum; in the one case, the metals imparting hardness and other useful qualities to the aluminum, and in the other the aluminum giving useful qualities to the alloying metals. The addition of a few per

cent of silver to aluminum, to harden, whiten, and strengthen the metal, gives an alloy especially adaptable for many fine instruments, tools, and electrical apparatus, where the work upon the tool and its convenience are of more consequence than the increased price due to the addition of the silver. The silver lowers the melting-point of the aluminum, and gives a metal susceptible of taking a good polish and making fine castings. Titanium and chromium can be readily alloyed with aluminum, according to the methods devised and patented by Prof. John W. Langley, and will probably prove to be the most valuable means of hardening aluminum. A few per cent of titanium renders the metal, under work, very rigid and yet elastic at the same time. Chromium is the best element to harden aluminum in castings. More or less useful alloys have been made of aluminum with zinc, bismuth, nickel, cadmium, magnesium, manganese, and tin, these alloys all being harder than pure aluminum; but it is by combination of these metals, with perhaps additions of copper, lead, and antimony, that alloys of most value have so far been discovered. Some are with additions of only 1 to 2 per cent of aluminum. The additions of from 5 to 15 per cent of aluminum to type-metal composed of 20 per cent antimony and 80 per cent lead makes a metal giving sharper castings and a much more durable type. To ordinary brass the addition of aluminum, especially in the form of aluminized zinc, an alloy of zinc with a few per cent of aluminum, gives superior strength and better anti-corrosive characteristics. Some very marked and valuable qualities have been discovered in the use of aluminum with zinc for various purposes. Additions of from ½ to 2 per cent of aluminum to Babbitt metal of a composition of copper 3·7 per cent, antimony 7·3 per cent, tin 89 per cent, gives a very superior bearing metal.

Methods of Aluminum Manufacture.—Aluminum can not be reduced from its oxide by the aid of carbon as a reducing agent by any of the ordinary methods, because the temperature to which the intimate mixture of the solid carbon and the alumina has to be raised can only be attained by the highest heat of an open-hearth furnace or in the electrical furnace—a temperature at which the alumina reduced can not itself be accumulated into a molten liquid mass, and can only be retained by collecting it with a more stable metal, such as iron or copper. None of the other salts is susceptible of being reduced by carbon at much lower temperatures than the oxide, so far as yet discovered. The task of producing aluminum at a low cost has thus been found to be a difficult one, and many unsuccessful attempts have been made and much money has been lost upon it. Debarred from using carbon as the reducing agent under the ordinary conditions which make it the practicable and economical reagent in most metallurgical operations, the advantages of other stronger reducing agents have been carefully tried. So far only one has proved commercially available, although there are other agents capable of reducing the metal from its salts. Metallic sodium reduces the metal from its chloride or from its fluoride salts readily at a red-heat. Methods based upon the use of sodium as the reducing agent have until lately given not only the purest but the cheapest aluminum. These methods, however, of late have been superseded by the cheaper and more direct processes of electrolysis of some of the aluminum salts or of the pure oxide.

History of Manufacture.—Davy, after succeeding in isolating metals of the alkaline earths, tried in vain to separate aluminum from its oxide, alumina. In 1826 Oerstedt formed aluminum chloride by passing chlorine over a mixture of alumina and charcoal heated to redness in a porcelain tube, but tried in vain to decompose this salt with sodium or potassium. In 1827 Wöhler, by better precautions to prevent oxidation, succeeded by the aid of potassium in reducing aluminum from the chloride in the form of a fine gray powder. It was very impure, and was only a metallic curiosity. In 1845 Wöhler obtained the metal in good-sized globules. Deville, twenty-seven years after the first isolation of the metal, in 1854, was the first to produce the metal in any quantity or with any degree of purity. It is curious to note that the first pure aluminum made was by electrolysis; both Bunsen and Deville reduced the double chloride of aluminum and sodium by electricity generated by galvanic batteries. Even then the idea of using electricity was old, for Sir Humphry Davy, in 1810, publicly described the successful experiment made in 1807, in which he connected the negative pole of a battery of 1,000 double plates with an iron wire which he heated to a white heat and then fused in contact with moistened alumina, the operation being performed in an atmosphere of hydrogen. The iron, upon analysis, was found to be alloyed with aluminum. Le Chatelier obtained English patent No. 1,214 in 1861, and Monckton, in 1862, English patent No. 264, for the reduction of aluminum by the aid of electricity. The Monckton patent proposes to pass an electric current through a reduction-chamber, and in this way to raise the temperature to such a point that alumina will be reduced by the carbon present, this evidently being the incipient idea of the electric furnace. Gaudin in 1869, Kagensbusch in 1872, Berthaut in 1879, and Grätzel in 1883 each brought out processes for producing aluminum by the aid of electricity. The newer pure aluminum processes using electricity, of Hall, Heroult, and the Bernard Brothers, with the help of Minet, together with the alloy processes of Cowles and Heroult, are the only ones now being worked upon a commercial scale. About 1857 the famous works at Salindres was established, under the proprietorship of Pechiney & Co., and this establishment, until within the past three years, produced a larger amount of aluminum than any other in the world. The care and skill shown and the ingenious devices and precautions taken by the firm to prevent impurities in the metal in the cumbersome and expensive sodium process in which there were so many opportunities for their addition, were worthy of the highest praise. In 1860 Sir I. Lowthian Bell started to manufacture aluminum at Newcastle-on-Tyne; the undertaking was abandoned in 1874; the sodium process was used. From 1874 until 1882 the French company at Salindres was the only concern making pure aluminum. In 1882 Webster organized the "Aluminum Crown Metal Company" at Hollywood, near

Birmingham, England, and by cheapening the production of aluminum chloride soon developed a successful concern. This was further strengthened by the improvement of H. Y. Castner, an American chemist, who in 1886 patented improvements for producing a more intimate mixture of the carbon with the caustic soda in a state of fusion by means of carbide of iron, in this way cheapening by more than one half the cost of manufacture of metallic sodium. This concern was organized under the name of the Aluminium Company, Limited, and put up a large and expensive plant at Oldbury, near Birmingham, England. These works were started at the end of June, 1888, and continued manufacturing until 1890. In common with other manufactures by the sodium process, they have been working to great disadvantage since the advent of the more successful electrolytic processes, and in 1891 ceased operations in the manufacture of aluminum. Early in 1888 the Alliance Aluminum Company started a works at Wallsend-on-Tyne, England, using a process which was an innovation upon the Deville sodium process, and employing the fluoride or the double fluoride of aluminum and sodium cryolite as the compound to be reduced instead of the chloride or the double chloride of the metal. Prof. Netto, the managing director of the concern, also has a process for producing metallic sodium cheaply, by allowing fused caustic soda to trickle over incandescent charcoal in a vertical retort. Some very excellent aluminum was produced at this works. The Hall process consists in electrolyzing alumina dissolved in a fused mixture of fluorides of aluminum and sodium, or, in fact, as Mr. Hall has described in his letters patent No. 400,766 a fused bath in which the alumina is dissolved in the fluorides of aluminum, together with the fluoride of any metal more electro-positive than aluminum. A volt-meter is attached to each pot, showing increased resistance when the ore gets out of the solvent by electrolysis, and at this time the pot-tender stirs in more ore. The feeding is thus easily made continuous, and as the fluoride solvent remains constant it only requires tapping the metal off—or, as is rather crudely but very satisfactorily done, dipping the metal out in cast-iron ladles, skimming the electrolyte back into the pots with carbon rods—to make the entire operation continuous. The cost price for the manufacture of aluminum by direct electrolysis has been brought down very low as compared with the cost of the more complicated processes of a few years ago, the items being: Two lbs. of alumina, containing 52·94 per cent aluminum. One lb. of carbon electrodes. A small expenditure for its proportionate share of the fluoride salts used for dissolving the alumina. Carbon dust, carbon pot-linings, and the metal pots. About twenty electric horse-power exerted per hour per lb. of metal made. Labor and superintendence, general expenses, interest, and repairs. As the Pittsburg Reduction Company uses the process, it places the mixture of fluoride salts, either in a solid condition or fused by the aid of external heat, in a row of carbon-lined wrought-iron tanks placed in series. The pots, together with their carbon linings and the reduced metal in the bottom of the pots, become the negative electrodes or cathodes. The positive electrodes or anodes are a series of carbon cylinders, 3 in. in diameter, attached by ⅝-in. copper rods to the copper conductors by the aid of suitable binding screw clamps. A current of large volume is turned on and the mixture, if solid, is melted by the electrically produced heat, when, in less than two hours' time, the mixture becomes fluid, and alumina is added. The electrolyte then becomes a much better conductor, "the resistance of the pot" goes down to a normal one of about eight volts, and the operation of electrolysis commences. The alumina in solution is decomposed; the metal, being heavier than the electrolyte, sinks to the bottom of the pot, and the oxygen goes to the positive electrode, uniting with a portion of the carbon and escaping as carbonic-acid gas. The Hall process can be successfully carried on entirely independent of carbon, using a thick iron or copper tank and either iron or copper electrodes. The deposition of the metal is nearly as large as with the use of carbon electrodes; but it is, of course, alloyed with copper or iron from the metal worn away from the positive electrode. The process called the "Minet process," as developed and used at the works of the Bernard Brothers at Creil, Oise, France, consists in electrolyzing a mixture of sodium chloride with the double fluoride of sodium and aluminum, their English patent dating July 18, 1887, No. 10,057. This company has been doing successful work, and is now putting aluminum of good quality on the market. In both the Cowles and Heroult processes aluminum is manufactured only in the form of an alloy. The principle involved is the interruption of a powerful electric current and the formation of an immense arc, and the reduction, at the high temperature produced by this arc, of alumina by carbon in the presence of either molten copper or iron. The Cowles furnace is a horizontal box, carbon-lined, having the current carried to it through two 6. in round carbon cylinders, which are arranged so that they may move forward and back in the furnace, which is filled with broken pieces of carbon and alumina mixed with the carbon and with turnings of iron or copper. The whole of the interior of the furnace is raised to a very high temperature by the electric arc formed, and the alumina present is reduced by the carbon and alloys with the metal. In the Heroult process the electrodes are vertical instead of horizontal. The alumina is fused by the electric arc, and, floating on molten copper or iron, is then treated as though it were an electrolyte; the carbon rod dipping into the molten alumina being the positive pole, and the molten iron or copper the negative electrode, which is in contact with the negative pole of the conductor. It is probable that there is considerable electrolytic action upon the molten alumina in the Heroult furnace for the reduction of aluminum, as well as a direct reduction of the oxide by the carbon. The Aluminium Industrie Actien Gesellschaft, at the Falls of the Rhine, Neuhausen, in Switzerland, claim to produce from 25 to 30 grammes of aluminum per horse-power per hour, in the form of a 10-per-cent aluminum-copper bronze.

Aluminium Bronze: see Alloys. **Aluminium in Steel**: see Steel Manufacture.

Amalgamator: see Mills, Gold, and Mills, Silver.
Ambulance: see Carriages and Wagons.
Ammonia Machine: see Ice-making Machine.

ARMOR. Early in the eighties iron was still to be found as a material for the construction of the hulls of battle-ships, and compound armor was in use by all the leading powers; the complete belt and armor had not yet begun its reaction toward special gun-position protection, and deck-protecting the ends had only just become a prominent feature. The French in the Marceau and Hoche and the Russians in the Dmitri Doushoi still held to the complete water-line belt. A change in gun-protection, however, is noted in the Hoche, a sister ship of the Marceau, in which the barbette with its light shield is changed to a completely covered barbette or modified turret. Each of the four heavy guns is carried in a separate armored redoubt—an arrangement of the primary battery rather costly in weight of armor.

The Italians, in the Lauria class, revert to the partial belt, with armored decks for water-line protection, and a strong central redoubt, carrying the heavy guns in barbette. In this vessel of 11,000 tons displacement, the armor is steel, 19·7 in. in thickness, and the hull is also of steel; the ends are not armored. In this same year, 1881, the English, in the Impérieuse and Warspite, show French influence by the battery distribution and its protection. The heavy guns are in separate positions in barbette; a heavy protective deck runs fore and aft, the midship portion being protected by a compound armored belt, 10 in. thick, about one third the length of the vessel.

The English started in this decade by building barbette ships with armored ammunition-tubes, but provided no protection immediately below the barbettes (see Fig. 1). There is a protective deck, but the armor belt for water-line defense, though thick, is very short. This typical ship, the Collingwood, was followed by five of the same class, all of which carry a secondary battery of 6-in. guns. In these vessels the armored barbettes are carried at a considerable height above the armored portion of the hull. In the strength of the protective armor on the tubes and in the general protection of the loading arrangements and gun-mountings, the belting of these vessels has been considered far superior to those found in most foreign war-ships. It was decided, however, in view of the great development of high explosives, that in any new designs for barbette ships the proportion of the length at the water-line protected by the belt of armor should be greater in new vessels of this same general type; and, further, that the armored barbette towers should be carried down to the top of the belt, in order that there should be no possibility of the bursting of shells, containing large explosive charges, under the floors of the barbettes upon which the revolving gun-platforms are carried.

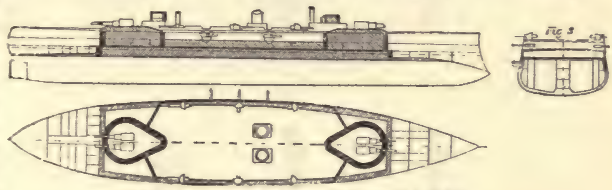


Fig. 1.—English type of barbette ship.

In 1883 the Russians, in the Tchesma, follow closely the then prevalent Italian idea of a central citadel, and have a heavily armored central redoubt. The complete water-line belt is given up, the ends being protected by a 3-in. armored deck. The six heavy guns, still in barbette, are mounted on disappearing carriages. The hull of this vessel is of iron and steel, the armor being composed of 18 in. thickness in the heaviest portions. The first Re Umberto, 13,300 tons, proposed in 1884, was the heaviest vessel designed up to that time. The heavy guns were in barbettes at either end of the vessel, being protected by steel armor 18·87 in. thick, the ammunition-tubes had 14·11 in. of armor, while the protective deck was 4·72 in. at its thickest parts, over the machinery, tapering and running to the extreme ends of the vessel. The auxiliary battery was in an unarmored casemate between the positions of the large guns.

In the Russian Alexander II the isolated armor on gun positions is reduced in thickness and spread over a larger and continuous area; the barbette is forward and protected by 10 in. of compound armor. The spur is also heavily armored; the auxiliary battery is carried in recessed ports having 6 in. of protection. In 1885 the English produced the Victoria, in which a departure was made from their former types of battle-ships. There is an armored belt amidships, 18 in. in thickness, and covering about one half the length of the vessel; then there is another belt, 6 in. thick, to protect that portion of the upper deck abaft the turret, and forming a casemate. The barbette mounts for the large guns are abandoned for a turret having 16 in. of armor, and placed on top of a supporting base also carrying armor 16 in. in thickness; a 3-in. protective deck runs fore and aft.

The Collingwood class is continued, though by vessels of a larger displacement, a somewhat superior type of battle-ship being presented by the Trafalgar and Nile in 1886. Most demands are well met in this class, but the secondary battery is somewhat weak. It was originally designed to be composed of eight 5-in. guns in broadside, without any protection, but was changed to six 4·72-in. rapid-fire guns behind 4 in. of armor. The irresistible logic of events had at this time forced the displacement above 14,000 tons; the water-line defense continued about the same. Few, if any, armored vessels with complete or partial water-line belts have these of sufficient depth to give proper protection when rolling. This defect is minimized, of course, in the large ships of from 13,000 to 15,000 tons displacement, which

were not found to roll appreciably in any sea-way that permitted ordinary vessels to work their guns.

In the barbette ships there was greater freeboard at the ends, four heavy guns placed high above water in two separate barbettes, and a central battery, containing an auxiliary armament identical with that provided for in the turret ships. In the strength of the protective armor are the ammunition-tubes, and in the general protection of the loading arrangements

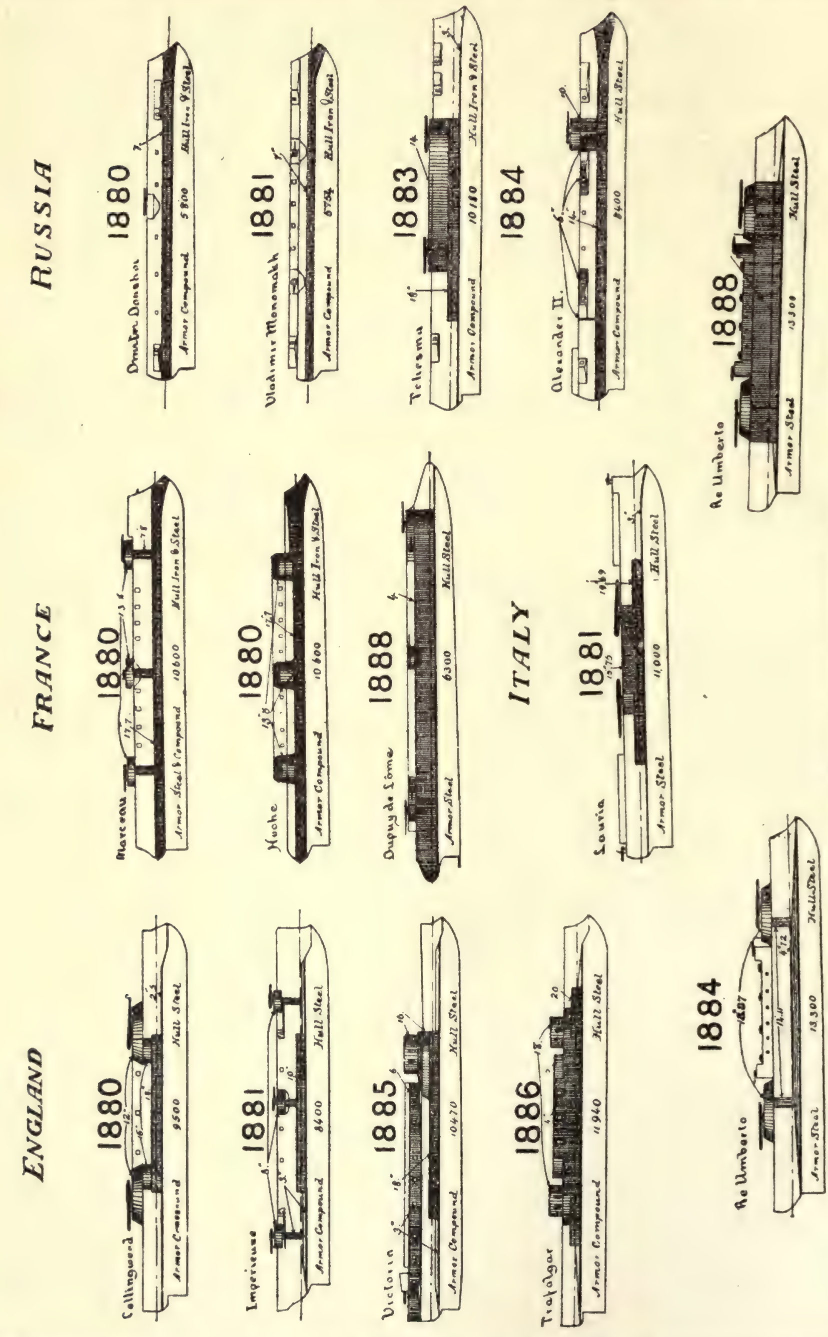


FIG. 2.—The development of English, French, Russian, and Italian armored vessels.

and gun-mountings the English type of barbette (Fig. 2) is held to be far superior to that to be found in most foreign war-ships. It was decided, however, in view of the great development

of high explosives, that in any new designs for barbette ships the proportion of the length at the water-line protected by the belt of armor should be increased, and that the armored barbette towers should be carried down far enough to prevent the possibility of the bursting of shells under the revolving gun-platforms.

Before proceeding to build new ships a most animated and prolonged discussion arose in 1888 in England, in which the leading naval architects participated, and which brought forth a great number of new features that are to be found in the battle-ships at present under construction. The adoption of the redoubt system, when it is associated with a long central battery containing a powerful auxiliary armament, enables a very appreciable increase to be made in the defense of the turret base, the turret guns, and all the loading appliances, as compared with what is possible when the continuous citadel is adopted. The defense afforded by the side armor fitted above the belt is re-enforced by continuous coal-bunkers which, when filled, contribute to the defense, and, when empty, form cellular compartments in rear of the armor. During the first half of this past decade it was but rarely that the projectile energy was entirely expended in making a clean hole through either compound or steel plates, the results usually obtained being a fractured plate and broken projectile. In conseqence, except in competitive trials of different plates of the same dimensions under exactly similar circumstances, all calculations or comparisons were too unreliable to be of value, the outcome being to leave the question of the relative merits of compound and steel armor an open one. Such have been the improvements in the quality of metal and in the processes of manufacture, and the conditions have varied so much from preceding ones, that the entire subject of armor must now be somewhat differently treated, and the outcome of trials that occurred before the middle of the decade set aside as hardly pertinent to the question.

The improvements in the quality and in the manufacture of projectiles have been relatively much greater than in that of plates, and armor-piercing projectiles are now produced which, so far as compound and steel plates are concerned, can from their perfection of quality, toughness, and temper, be fairly dominated as unbreakable and undeformable. As soon as such projectiles were obtained, a fairly approximate method of comparing, under certain fixed conditions, the resisting powers of different plates to penetration was arrived at. Armor trials have thus far been conducted under conditions exceedingly unfavorable to the plate, more so than would probably ever occur in actual warfare. The gun has every advantage: a steady platform and a normal impact at a short range on an immovable target, so rigidly braced as to receive the full effect of the energy stored up in the projectile.

In 1888 a Cammel compound plate, 8 ft. by 6 ft. by 10½ ft. thick, was tested in competition with a number of English-made compound and steel plates, and not only proved superior to all its competitors, but gave better results than had ever before been obtained from a compound plate under similar conditions. The most important point brought out in regard to this plate was the decided uniformity of the metal of which it was composed, this being evidenced by the nearly equal penetration of the three Holtzer 100 lb. armor-piercing projectiles, having a striking energy of 2,723 foot-tons, and the similar amount of work done on each, they all breaking in about the same manner. The chilled-iron Palliser projectiles broke up against the hard steel face with but slight penetration.

In November, 1889, off Helder, North Holland, there were competitive tests of compound armor-plates, each weighing 12·4 tons and being 11·02 in. thick. Three of the plates were manufactured on the Wilson system by Cammel, St. Chamoud, and Marrel, respectively, and the fourth on the Ellis system by Brown. The gun used was a Krupp, 11·02 in. caliber, and firing forged steel projectiles weighing 556 lbs. The test was a severe one; the St. Chamoud and Marrel plates were so badly treated that they were out of the contest after the first shot at each; the Cammel plate was perforated with ease, much of the hard steel face separating from the soft back. The Brown plate stopped the first two projectiles, but not the third, and is considered to have behaved excellently. (See Fig. 3.)

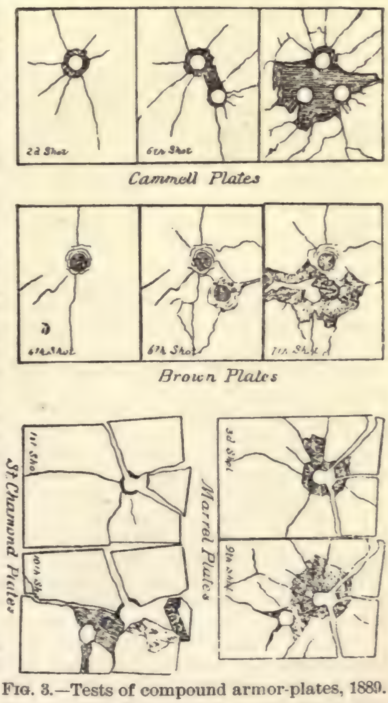


Fig. 3.—Tests of compound armor-plates, 1889.

In 1890 there was another test given a Cammel plate, 8 ft. by 6 ft. by 10½ in. thick, the projectiles for the 1st, 2d, and 5th shots being 100 lbs. Holtzer, and for the 3d and 4th shots 98 lbs. Palliser. This plate was greatly outmatched by the projectiles; not only was the penetration very deep, but the hard steel face suffered much more. From this it was judged that the improvement in the Cammel compound steel-faced armor-plates had about reached their limit. The lack of uniformity in results obtained under similar conditions, and the frequent scaling off of the hard steel faces in these and many other trials were thought to be sure

indications of imperfect welding. Against brittle projectiles like the Palliser the compound plates acted to greatest advantage.

Of a number of English-made steel plates which were tested in 1888 but two gave results at all comparable with those obtained from the competing compound plates, a decided lack of uniformity in the metal being very apparent. A steel plate made by Vickers gave better results. The equal penetration and the very similar effects on the armor-piercing projectiles gave evidence of great homogeneity of the plate. The elasticity of the metal was well exemplified by the rebounding of the projectiles, and its comparative softness by the effect on the back of the plate. A large order from the English Government followed the satisfactory showing of the Vickers plate.

In 1888 the French fired chilled cast-iron projectiles of 83·8 lbs. against Schneider steel plates 5½ in. thick. Each of the projectiles was broken in about the same manner, and their penetrations not being in proportion to the projectile's energies, it was concluded that the metal lacked uniformity. Later, the same year, a heavier plate, 9·6 in. thick, was fired at with chilled cast-iron projectiles weighing 99·2 lbs. with most excellent results, homogeneity of the plate being clearly demonstrated. The plate, however, greatly outmatched the projectiles. In May, 1890, a Schneider plate was again fired at, and behaved much better than in either of the preceding trials. In July of the same year plates of the same make were fired at with Finspong armor-piercing cast steel. The similar effects on plate and projectiles indicated satisfactory uniformity, and the plate was considered superior in resisting power to any Schneider plate previously tried. It also demonstrated the practicability of forming steel into curved plates without detracting from the resisting power of the metal.

We now come to what were considered the most important and conclusive armor trials ever undertaken by governmental officials. These are interesting, not only on account of the definiteness of the results obtained, but also from the fact that in each case the plate which fairly carried off the honors was neither one of the old-time rivals—English compound and Schneider steel—but was an alloy of nickel with steel. In addition, the projectiles used were so little damaged on impact that the effects on the competing plates can be fairly compared, a matter of considerable difficulty in earlier trials. The trials at Ochta are given first, as the nickel-steel plate tested there was made a year previous to that used in the Annapolis test in this country.

The trial took place at the Ochta naval battery, in Russia, and three plates were submitted. A Brown (Ellis patent) compound plate, a Schneider nickel-steel plate, and a Vickers all-steel plate, each 8 ft. square, about 10 in. thick, and 11·7 tons weight. The gun was a 6-in. 35-caliber, firing a Holtzer 89·38 lbs. Five shots were fired at each plate; the first two were not so well tempered as the remaining three. Here the Brown plate was completely outmatched; in addition to an unexpected degree of penetration, it was also badly fractured, an unusual occurrence when a compound plate of such thickness is attacked by small projectiles, but the slight scaling off of the hard steel face showed that the welding was excellent. Its performance proved that it did not merit classing with its competitors.

The Vickers plate did comparatively well, but its resisting power was far below that of the Schneider plate, this being clearly shown by the greater penetration, and by the less amount of work done on the projectiles. Being much softer than the Schneider plate, it was much less shattered. Its back was bulged out considerably by the first shot, enough to have badly bent any framing behind it. The remaining shot did not cause any great bulging at the back, but, instead, the metal was clipped out around the shot-holes. After the trial, although considerably cracked, it was removed from its backing without having the cracked parts separate. Its lack of homogeneity was shown by the difference in penetration of the last three projectiles—17·21 and 14 in., respectively—all of which remained unbroken.

The Schneider nickel-steel plate did not show up as well as was expected, cracking more than Vickers, but it proved best of all for armor protection. Only two of the projectiles got their points beyond the back of the plate. When removed from the backing, this and the compound plate had to be banded to keep their fractured parts from separating. The rebounding of the projectiles from this plate showed it to be more elastic than the all-steel, the latter acting more like good wrought iron when attacked by projectiles of excellent quality. One especially noticeable feature was the little effect of its many cracks on the penetration of succeeding projectiles. As a result of this trial, Schneider obtained a contract for 2,100 tons of armor for the Russian battle-ship Georgy Pobedonetz, and Vickers an order for 300 tons of steel plates, from 3 to 5 in. thick, for two Russian gunboats.

The first most important trials in this country were held at Annapolis in September, 1890, at which three plates were presented, one of steel and one of nickel steel, by Schneider & Co., Le Creusot, France, and one compound plate by Cammel & Co., Sheffield, England. The plates weighed about 20,800 lbs., and were arranged on chords of a circle, with the gun-pivot as the center, and the muzzle of the gun 28 ft. distant from the center of the plate toward which it was pointed. The gun used on the first day was a 6-in. breech-loading rifle, 35 calibers long. The charge used was 44½ lbs. for each round; the striking velocity 2,075 ft. per second. The projectiles were Holtzer 6-in. armor-piercing shell, weighing 100 lbs. After four rounds had been fired at each plate, further firing was deferred until an 8-in. gun had been mounted in place of the 6-in. The charge was 85 lbs. of brown prismatic powder, the striking velocity being 1,850 ft. per second. The projectiles were Firth armor-piercing shell, weighing 210 lbs.

The compound plate was perforated by all projectiles, and its steel face was destroyed. Two of the shells passed completely through both plate and backing. Both steel plates kept

out all projectiles, the all-steel plate showing slightly greater resistance than the nickel-steel plate; but the former was badly cracked by the 8-in. shell, while the latter remained uncracked. The hard face of the compound plate was not only easily overcome by the projectiles, but was also nearly all scaled off from the soft wrought-iron back. The ease with which all the projectiles perforated was taken as proof that the plate fell far short of having 50 per cent greater resisting power than a wrought-iron plate of the same thickness. The soft wrought-iron back was, however, uncracked at the end of the trial. The effect of the larger projectile was out of all proportion to that of the 6-in., its recovery undeformed proving that all the work was done on the plate. No such great difference, at the corresponding shots, was found with either of the two other plates. A decided disintegration of the metal at each shot was noticed, on account of which successive shots encountered less resistance, as evidenced by the successive greater penetrations.

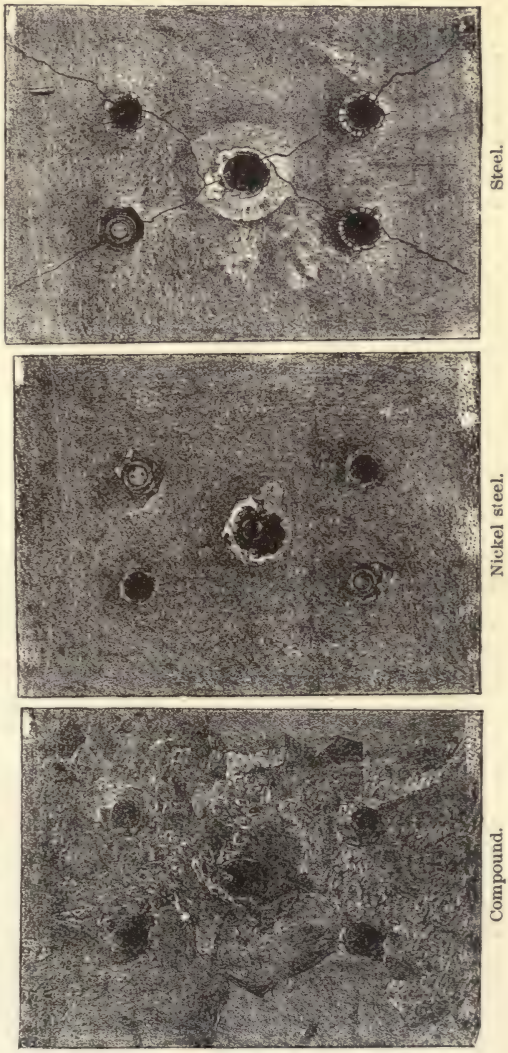


FIG. 4.—Annapolis tests of armor-plate.

At the end of the fourth shot at each plate a choice between the steel and nickel steel would have been in favor of the former, on account of the less amount of penetration. Up to this point the steel had proved itself the superior in resistance to penetration and fracture of any plate ever previously tested. Three of the four projectiles fired at it remained unbroken, which, with the equal amount of penetration in each case, gave unmistakable proof of the homogeneous character of the metal of the plate. Its great elasticity was evidenced by the rebounding of the projectiles, and the manner in which the metal came to the front and heaped up in regular fringes about the shot-holes.

But the nickel-steel plate gained the day at the fifth round, when the 8-in. projectile was broken in many pieces, after having forced its point but $10\frac{1}{2}$ in. beyond the back, and that without developing the sign of a crack. This plate showed the same amount of homogeneity as the steel one, but was tougher and more tenacious, as was shown by the gripping of the projectiles. The metal did not come to the front in fringes, but clipped off about the edges of the shot-holes. Much of the energy was expended in breaking up the projectiles, the localization of effect was very remarkable. At the last shot at the all-steel plate the 8-in. projectile succeeded in getting its point only 5·2 in. beyond the back. The plate, though, cracked in two cross-lines, which were so serrated that, when the plate was removed from its backing, the parts remained firmly in place. (See Fig. 4.)

The principle upon which compound armor is based is generally thought to be a good one, a hard projectile-breaking face and a graduated resisting back. Great efforts will probably continue to be made to harden the face of plates until the getting through of the projectiles is no longer a possibility. Several methods for applying this principle to armor-plates by processes resulting in superficial carbonization have been devised, and among them is that now known as the Harvey process. Each plate is treated with the design of transforming its surface into a high grade of steel, without causing its back to lose any of its original toughness, and without producing a pronounced plane of demarkation between the two qualities of metal. Plates treated by this process were subjected to trials at Annapolis, twenty-one shots from a Hotchkiss 6-pounder being fired at a 3-in. plate of nickel steel. Only three penetrated more than half an inch, and all projectiles were smashed.

By far the most momentous question which the Navy Department in this country has had to consider in connection with the construction of the new navy is that of armor: first, to secure a supply of American manufacture; and, secondly, to determine what kind of armor

should be adopted, having reference both to its composition and mode of treatment. The series of tests already referred to resulted in the decision to adopt nickel steel. It remained, however, to give a thorough trial to the first armor of domestic manufacture before beginning to place it upon the vessels, and for this purpose it was decided to order typical plates to test (1) whether our domestic manufacturers could produce an armor that would stand competition with foreign material, and (2) which of the various modes of treatment would give the best results.

Six plates were furnished and set up at Indian Head (1891), and they were subjected to tests more severe than had ever been applied to foreign government trials. Four shots were fired at each plate with a 6-in. gun, with an impact velocity of 2,075 ft. per second, using the Holtzer projectile of 100 lbs. One shot was then fired at the center of each plate from an 8-in. gun, with an impact of 4,988 foot-tons, or 2,000 in excess of the 6-in., using Firminy and Carpenter projectiles of 210 and 250 lbs. weight, respectively, the plates being normal to the line of fire. Three of the plates were furnished by the Bethlehem Iron Co. and three by Carnegie, Phipps & Co., some being rolled, others forged, and several being treated by the Harvey process.

The results of the trial were in the highest degree satisfactory. Each of the six plates manufactured in this country was superior to the English compound plate, while the nickel Harveyed plate and the high-carbon nickel plate were superior to all the foreign plates of the Annapolis trial. They may, therefore, be pronounced in advance of the best armor hitherto manufactured in Europe. Further light was thrown upon the question of the relative merits of all-steel and nickel-steel armor, and any doubt which may have remained upon that subject was finally set at rest. Of the three plates made at Bethlehem two were of nickel steel, one treated by the Harvey process, the other not, and the third was of all steel, Harveyed. Both the nickel plates proved to be far superior to the all-steel Harveyed plate, notwithstanding the advantages which it may have derived from the special treatment; and both proved superior to the French all-steel plate tried at Annapolis. A third nickel plate, manufactured by Carnegie, under the rolling process, also showed a marked superiority over the all-steel plate of this year, and both it and the corresponding Bethlehem plate manufactured under the hammer showed a capacity of resistance to perforation fully 10 per cent greater than that of the French all-steel plate. In this respect the results furnished by the two American plates manufactured by the different processes (forging and rolling) proved to be remarkably uniform, the 6-in. shots that were fired at them differing in penetration but an inappreciable amount. The trial thus definitely establishes the fact that armor of excellent quality may be produced by the rolling process, and that forging by means of the hammer, the greatest source hitherto of expense in manufacture, is no longer to be regarded as an absolute necessity. The importance of this fact can hardly be overestimated, for it raises a probability that within a year or two the armor-producing capacity of the United States may be quadrupled in case of necessity, and that if we had 10,000 tons to let, and could give eighteen months from date of contract to commence delivery, the cost of manufacture would be reduced from 25 to 33 per cent, while the work hitherto confined to two firms would be thrown open to a large number of competitors. Finally, the trial shows that the high-carbon nickel Harveyed plate is undoubtedly the best armor-plate ever subjected to ballistic test.

As a result of these trials orders have been placed with the firms mentioned for armor sufficient to cover the battle-ships, monitors, and armored cruisers now in course of construction in this country, and foreign governments that had not already ordered armor for new vessels have quite generally adopted the newer type. Other experiments are in progress to still further develop the qualities of nickel steel, as well as the process by which additional hardness is given to its surface.

The most powerful armored vessels of the United States at present (1892) being built are the Indiana (see full-page plate), the Massachusetts, and the Oregon. Each of these vessels has a water-line armor-belt 7½ ft. wide and 18 in. thick. Armored redoubts 17 in. thick at each end of the belt extend 3½ ft. above the main deck, and thus give an armored free-board of 15 ft. 2 in. These redoubts protect the turning-gear of the turrets, and all operations of loading. The turrets have 17-in. inclined armor. The 8-in. guns have barbettes of 10 in., inclined turrets of 8½ in., and loading tubes of 3 in. The side armor is backed by 6 in. of wood, two ⅝ in. plates, and a 10-ft. belt of coal. Above the belt armor the side is protected by 5 in. of steel. The protective deck is from 2¾ to 3 in. thick.

It is not alone to ships that armor is being applied: its use has been extended to the protection of guns on shore, particularly by France and Germany. Of late years great revolutions have taken place in the principles upon which such forts are constructed, and in the Gruson system is seen one of the most approved types of armored fortifications. In this system the conditions kept in view are that the protection must insure the most perfect freedom of action to the gun; the necessary men must be kept as low as possible, the construction must be light and easily movable, and there must be the utmost reduction of the interior space.

The Canet system differs in details from the above, although the conditions to be fulfilled are practically the same. In both there is heavy armor, for offering an efficient resistance to heavy projectiles, even when charged with melinite or other high explosive, sufficiently heavy not to be injured by the recoil energy set up by the firing of the guns. The latter are to be as far as possible independent of the turrets, and are mounted upon disappearing carriages, so that their crews are protected during the operation of loading. The plan is circular, and a masonry-lined pit is sunk as a basement for the gun-platform. A shield of steel or wrought

THE UNITED STATES ARMORED BATTLE-SHIP INDIANA.

iron protects the pit, a metal roof covering the whole. All the joints are made with mortises and dovetails, and are filled in with molten lead, the use of bolts being avoided. In addition to forts for permanent defenses, there are others made for use of rapid-fire guns in the field, which are transported from place to place by horses. See Tempering and Hardening, also Publications of Office of Naval Intelligence, United States Navy Department, 1892, and preceding years.

Bagger: see Thrashing Machines.

BALANCE, THE TORSION. The first successful attempt to make an even balance or other weighing machine with beams oscillating on pivots, which should dispense with knife-edges, and thereby avoid their well-known defects of liability to damage by wear, rust, and overloading, was made by Frederick A. Roeder and Alfred Springer, in Cincinnati, Ohio, in 1882. They used as a pivot a steel wire stretched tightly between abutments. The balance-beam being firmly attached to the wire, its oscillation caused the wire to twist slightly, hence the name "torsion balance." The simplest form of torsion balance is a very light beam supported at its middle point, which is also its center of gravity, by a stretched wire, the wire being firmly fastened to the beam. A weight placed at one end of the beam will exactly balance a weight at the other end. The sensitiveness of such a balance depends upon having the torsional resistance of the wire almost infinitely small. This requires a very thin wire, and as thin wires, when stretched horizontally, are not strong, the balance can be used only for very small weights. Such a balance was Ritchie's, mentioned in the *Encyclopædia Britannica*, and it was a total failure for large weights. If the wire is made large enough to have an appreciable strength, its torsional resistance prevents the balance being sensitive. To get rid of the effect of the torsional resistance in diminishing the sensitiveness of the balance was one of the chief ends of Messrs. Roeder and Springer's efforts. They accomplished it in a number of different ways, but the simplest, and the one which is adopted in practice, is the placing of the center of gravity of the beam above its point of support. In knife-edge balances such a placing of the center of gravity would make the beam top-heavy, or in unstable equilibrium; the center of gravity would always tend to reach its lowest point, and tip the beam. In the torsion balance, however, this top-heaviness acts in the opposite direction to the torsional resistance of the wire, and may be made to entirely neutralize it. We thus have the torsional resistance exerted to keep the beam horizontal, while the high center of gravity tends to tip it out of the horizontal. The adjustment of the position of the center of gravity so as to neutralize the torsional resistance is most easily made by having a poise placed immediately above the center of the torsional wire, and making it adjustable vertically by means of a screw and nut. When the torsional resistance is entirely neutralized, the balance becomes infinitely sensitive, and any smaller degree of sensitiveness that may be desired may be obtained by simply lowering the poise. The torsion balance is made in many forms, but in general the wires are shaped like a thin flat band in section; instead of being round, the two ends of a strip are brazed together so as to make a ring, and this is tightly stretched over a frame or truss of steel or other metal, of the shape shown in Figs. 1 and 2. In an even-balance scale three of these frames are used, and two beams, an upper and a lower. The end wires are ·25 in. wide by ·010 in. thick. The practical sensitiveness of this scale, when vibrating at the rate of 10 oscillations per minute, is about 2 grains.

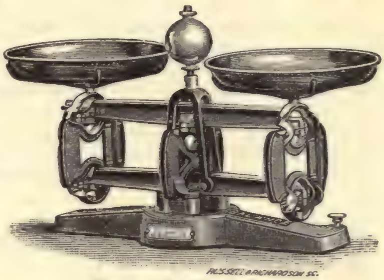


FIG. 1.—Torsion balance.

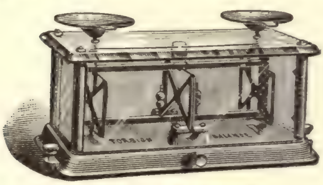


FIG. 2.—Torsion balance.

Fig. 2 shows a druggist's prescription balance sensitive to $\frac{1}{64}$ grain in actual use. It has a capacity of 8 oz. in each pan. The wires are about ·04 in. by ·004 in. Their torsional resistance is overcome by the small round weight seen in the cut attached to studs on the lower beam. See *Trans. A. S. Mining E.*, vol. xii, p. 560; *Trans. A. S. M. E.*, vol. vi, p. 651.

BALANCING WAY. A device for balancing mechanism to be rotated, such as cutter-heads, pulleys, armatures, etc., consisting of a frame, with two planed ways, on which are mounted two standards, one fixed, and the other movable. The top edges of the standards are planed true and form the "ways," on which the work is rested while being tested for "balance."

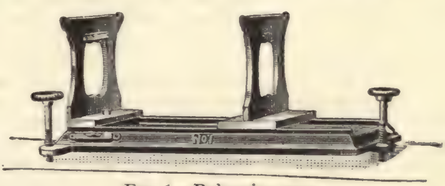


FIG. 1.—Balancing way.

Bale Breaker: see Cotton-spinning Machine.

Balling Machine: see Cotton-spinning Machine.

Balloon: see Aërial Navigation.

Band Cutter: see Thrashing Machines.

Band Saw: see Saws, Metal Working and Saws, Wood.

Barrel, Chlorinating: see Mills, Gold.

BARREL-MAKING MACHINES. In the manufacture of both tight and slack barrels, and more especially in the latter, machinery is used to an extent which is increasing year by year; and the indications are that even in tight barrel-making, at least where the barrels are not to contain very expensive liquids, hand-work will be superseded by better and cheaper work done by machinery. In this line there are but few manufacturers, and among these not more than one or two who make a full line, enabling a cooperage establishment to be started with facilities for making every part of every kind of a barrel, to be both made and put together by machinery. From the multiplicity of machines for making parts of barrels or for assembling them into complete wholes, ready for shipment, we can make but a limited selection.

Stave-Jointer.—In the ordinary stave-jointer there is employed a knife at least as long as the stave is to be, and having its edge ground to a double slope—that is, the blade has a straight back, but is widest in the middle, its edge being composed of two straight lines meeting at an obtuse angle. This gives a draw cut both ways from the center. The knife is also bent to a degree corresponding to the amount of bilge; and the shook being clamped in place, the knife, which slides guillotine-like, is brought down by foot-power and returned by springs.

Lock-Cutter.—The power lock-cutter is used for cutting locks on wood barrel-hoops of different lengths and widths in their proper position, without changing the machine for hoops of different sizes, and chamfering the ends of the hoops. There is a rotary cutter-head bearing cutters which are nearly straight on their edges. This cutter-head is so formed that the hoop can be and is pressed against it without danger of drawing the hoop into it. The clamp that holds the hoop while being cut is adjustable horizontally and vertically, giving capacity for changing the form of the lock and of the hook.

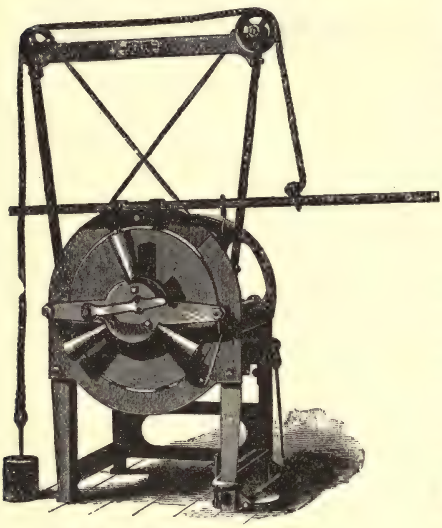


FIG. 1.—Hoop-coiling machine.

An Automatic Hoop-Coiling Machine is shown in Fig. 1. This serves for coiling slack barrel and keg hoops of various sizes and lengths. There is a circular head about which the hoops are coiled, which is driven by an internal friction gear attached to the back end of the head spindle, and is operated by a tarboard friction-pulley running in lever-boxes, and which are connected to a foot-lever. One end of the hoop to be coiled is inserted in an open slot in the rotating head while the machine is in motion, firmly securing the end of the hoop to the head while coiling around the disk. Each succeeding hoop is fed into the machine at the proper time to allow the preceding loop to form a lap. A steel spring is used in binding the coil firmly together. The end of the last hoop is secured to the coil by a single nail. The cone-shaped rollers shown in the figure in front of the face-plate serve as guides in keeping the hoops snug against the face-plate. These rollers are attached to a sliding carriage which has an adjustable weight for giving proper tension to the rollers from the face-plate. A three-armed spider back of the face-plate, with the arms projecting through it, slides in a horizontal plane with the rolls. After the coil is finished the weight of the operator's foot upon the lever simultaneously carries the rolls and the spider forward enough to have the coil clear the disk, when the coil is automatically discharged from the machine without stopping. The capacity of the machine is from 1,500 to 1,800 hoops per hour.

A Compound Hoop-Guide and Wood Hoop-Driving Machine, for guiding wood hoops on to barrels in process of manufacture, is formed by coned sections attached to and controlled by slides and springs, and moves in and out by turning a hand-wheel. It is used in connection with the hoop-driving machine of the same firm, which is driven by a combination of friction and screw power, which moves the driving arms and drivers up and down, the upward motion being more rapid than the downward, and the sectional drivers which move the hoop nearly surround the barrel, being circular in form. In using this machine in connection with the hoop-guide, the guide is placed on the head of the barrel, and a hand-wheel is turned, which moves out the cone sections a little beyond the edge of the end of the barrel. The wood hoops are then placed on the cone, and the hoop-drivers receive them and drive them to their proper position. In driving the small hoops, the cone-sections recede to the size of the hoop and guide it on to the barrel. Both the hoop-guide and the hoop-driver are adjustable for different sized barrels. This machine and the guide fill a place in the line of labor-saving machines for making wood-bound barrels for liquors.

Basic Process: see Steel Manufacture.

Bean Harvester: see Harvesting Machines, Grain.

BEARINGS. ROLLER AND BALL BEARINGS.—The use of rollers and balls in bearings for the purpose of converting sliding into rolling friction is meeting with success in numerous

special cases. The most general application of ball-bearings is in bicycles (see BICYCLE). They have also been used to some extent for axles of mining-cars. An application of roller-bearings in the main journal of the great Lick telescope is thus described by W. R. Warner (*Trans. A. S. M. E.*, vol. ix, p. 330). The tube is 56 ft. long, and weighs 4½ tons. It is supported on a bearing near the center and at one side. It seemed almost impossible to make it move easily enough in the ordinary way by using friction-rolls; so, instead of that, the method was adopted of surrounding the axis close to the tube with a series of rolls 2½ in. in diameter and 3 in. long, with a result which seemed very satisfactory. The tube when balanced on these rolls would turn by a pressure of 4 lbs. at the end—one finger would move it very easily—so that the problem was as completely solved as could be asked. Another effort to solve a similar problem in a different position, where the rollers hardly would do, was accomplished by using hardened steel balls running in circular concave tracks, which is the same principle used in bicycle-wheels. In this problem, simply to test its working, a weight of 2½ tons was placed on 40 1-in. balls in the two circular tracks, and this 2½ tons was turned by a pressure of 1 lb. at a radius of 3 ft. The groove in which the balls run had a diameter of $1\frac{1}{16}$ in., so that it was practically a plane surface, bearing only on the top and lower edge, and the balls worked together so that the whole ring, when they were pressed together, left only $\frac{1}{32}$ in. between the last two balls. In the case of the rolls, they were not together, but had their axis run on little steel balls $\frac{1}{16}$ in. in diameter. There was no lubricant. It was found safe to put on the balls something less than 1,000 lbs. to each ball, while on a roll having its bearing surface its full length—3 in.—a much larger weight could be placed.

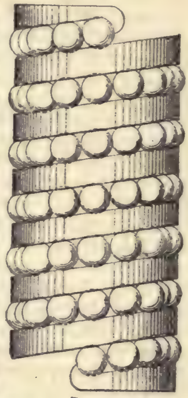


FIG. 1.—Ball bearing.

In the ordinary form of ball-bearings the track or tracks in which the balls roll soon becomes worn if the bearing is subjected to any considerable pressure, this seeming to be a necessary consequence of the fact that only a very small portion of the actual surface within such a bearing can be used by the balls. It has been demonstrated that a bearing does better without grooves for the balls to run in than with them, the plain surfaces being not only more easily produced, especially when hardened and ground as they should be, but actually working better in nearly every respect. This being the case, it became a problem to so arrange the balls that all the surface within a bearing, both on the shaft and within the box, should be made use of by the balls, thus preventing wearing in grooves, as is the case where they are arranged in rings, separated from each other by collars. Figs. 1 and 2 show forms of bearings in which the balls are held in what is virtually a shell that can be removed from the bearing, handled and put in again without a single ball being displaced. It will be seen that the balls are arranged between the coils of a helix which holds them loosely, so that they are free to turn, the ends of the helix being partially closed to prevent their running out at the ends. The sides of the strip from which the helix is formed are made concave, as shown in Fig. 2, the object of this being obvious. The shell or helix is not held in the bearing in any way, except that collars prevent it being displaced endwise, and it turns freely with the balls as they rotate. Though arranged in a helical line, the balls do not rotate in this line, but in a direct annular direction in a plane at right angles to the center line of the journal, the pitch of the helix being so proportioned to the diameter of the balls that each succeeding ball rotates in a track which is slightly at one side of that of the preceding one (usually about $\frac{1}{64}$ in.), the end play which is in most bearings allowing for enough movement to cover the intervening spaces, so that the entire surface is made use of, both the shaft and the box becoming planished brightly and uniformly over their entire surface. Experience has shown that this results in decrease of wear. Fig. 3 shows another form of bearing, which embodies the same principle, so far as the distribution of the balls is concerned, they being in this case inclosed in a shell of brass, which is drilled, as shown, for the reception of the balls, a shoulder being left at the bottom of the holes, and the tops being partially closed after the balls are in place, so that they are held loosely, as in the helical shell. One of the advantages of this form is that more balls can be put into a bearing of given size, and the shell can be made in two parts, joined together as shown, so that they can be put over a shaft or taken from it at any point in its length without the necessity of going to the ends. The two parts are joined at the irregular line shown, and are held together by the spring hooks seen at the sides. It will be understood, of course, that not much force acts to separate the two parts of the shell when it is in use, since its only office is to keep the balls properly separated.

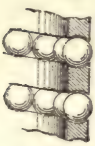


FIG. 2. Ball bearing.

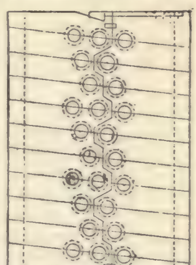


FIG. 3.—Ball bearing.

Bearings: see Drilling Machines, Metal; also Cycle.

Belt Lacing: see Belts.

BELTS. Recent experiments on belting (see *Trans. A. S. M. E.*, ii, 91 and 224; vii, 347 and 549; viii, 529; and x, 765) all tend to confirm the statement made in Vol. I of this work, that "experiments on the amount of power that can be transmitted by a belt of given size show many discrepancies, which seem to be due to the fact that belts of different quality were experimented upon; and it is pretty well settled that, while rules can be constructed

that will show what power a good belt *may* transmit under given conditions, they can not be implicitly relied upon to show how much power a particular belt *does* transmit."

An elaborate set of experiments on belts was made in 1885 by William Sellers & Co., and reported by Mr. Wilfred Lewis (*Trans. A. S. M. E.*, vol. vii, p. 549). These experiments seemed to show that the principal resistance to straight belts was journal-friction, except at very high speeds, when the resistance of the air began to be felt. The resistance from stiffness of belt was not apparent, and no marked difference could be detected in the power required to run a wide double belt or a narrow light one for the same tension at moderate speeds. With crossed and quarter-twist belts, the friction of the belt upon itself or upon the pulley in leaving it was frequently an item of more importance, as was shown by special experiments for that purpose. The experiments also showed that, in all probability, leather is more elastic under light tensions than it is under high ones. A piece of belting 1 sq. in. in section and 92 in. long was found by experiment to elongate $\frac{1}{4}$ in. when the load was increased from 100 to 150 lbs., and only $\frac{1}{8}$ in. when the load was increased from 450 to 500 lbs. The total elongation from 50 to 500 lbs. was $1\frac{1}{16}$ in., but this would vary with the time of suspension, and the measurements here given were taken as soon as possible after applying the loads. In all cases the coefficient of friction was shown to increase with the percentage of slip. An interesting feature of these experiments is the progressive increase in the sum of the belt tensions during an increase in load. This is contrary to the generally accepted theory that the sum of the tensions is constant. The highest coefficient obtained was 1·67, but, of course, this was temporary. The diameter of the pulley also appears to affect the coefficient of friction to some extent. This is especially to be noticed at the very slow speed of 18 revolutions per minute on 10-in. and 20-in. pulleys, where the adhesion on the 20-in. pulleys is decidedly greater; but, on the other hand, at 160 revolutions per minute, the adhesion on the 10-in. pulleys is often as good as, and sometimes better than, appears for the 20 in. at the same velocity of sliding. It might be possible to determine the effect of pulley diameter upon adhesions for a perfectly dry belt, where the condition of its surface remains uniform; but for belts as ordinarily used it would be very difficult, on account of the ever-changing condition of surface produced by slip and temperature. It is generally admitted that the larger the diameter the greater the adhesion for any given tension, but no definite relation has ever been established, nor, indeed, does it seem possible to do so, except by the most elaborate and extensive experiments. Theoretical formulæ hitherto used in calculations of belt-power have assumed the coefficient of friction as uniform around the arc of contact, but this can no longer be correct if the coefficient varies with the pressure. Mr. Lewis says the driving-power of a leather belt depends upon such a variety of conditions that it would be manifestly impracticable, if not impossible, to correlate them all; and it is thought better to admit the difficulties at once than to involve the subject in a labyrinth of formulæ which life is too short to solve. Mr. Lewis estimates that under good working conditions the efficiency of belt transmission may be assumed to be 97 per cent. When a belt is too tight there is a constant waste in journal-friction, and when too loose there may be a much greater loss in efficiency from slip. The indications and conclusions drawn from his experiments are as follows: 1. That the coefficient of friction may vary under practical working conditions from 25 to 100 per cent. 2. That its value depends upon the nature and condition of the leather, the velocity of sliding, temperature, and pressure. 3. That an excessive amount of slip has a tendency to become greater and greater, until the belt finally leaves the pulley. 4. That a belt will seldom remain upon the pulley when the slip exceeds 20 per cent. 5. That excessive slipping dries out the leather, and leads toward the condition of minimum adhesion. 6. That rawhide has much greater adhesion than tanned leather, giving a coefficient of 100 per cent, at the moderate slip of 5 ft. per minute. 7. That a velocity of sliding equal to ·01 of the belt-speed is not excessive. 8. That the coefficients in general use are rather below the average results obtained. 9. That, when suddenly forced to slip, the coefficient of friction becomes momentarily very high, but that it gradually decreases as the slip continues. 10. That the sum of the tensions is not constant, but increases with the load to the maximum extent of about 33 per cent with vertical belts. 11. That, with horizontal belts, the sum of the tensions may increase indefinitely as far as the breaking strength of the belt. 12. That the economy of belt transmission depends principally upon journal-friction and slip. 13. That it is important on this account to make the belt-speed as high as possible within the limits of 5,000 or 6,000 ft. per minute. 14. That quarter-twist belts should be avoided. 15. That it is preferable in all cases, from considerations of economy in wear on belt and power consumed, to use an intermediate guide-pulley, so placed that the belt may be run in either direction. 16. That the introduction of guide and carrying pulleys adds to the internal resistances an amount proportional to the friction of their journals. 17. That there is still need of more light on the subject.

Mr. Samuel Webber (*Trans. A. S. M. E.*, vol. viii, p. 537) proposes the following formulæ for leather belting, where the tension with which the belt is put on is known or assumed:

$$\text{Width in inches} = \frac{\text{No. HP.} \times 33{,}000 \times 180^\circ}{\text{velocity in ft. per minute} \times \text{strain in lbs. per in. width} \times \text{arc of contact}}$$

and

$$\text{HP.} = \frac{\text{velocity in ft.} \times \text{strain per in.} \times \text{width} \times \text{arc of contact}}{33{,}000 \times 180^\circ}.$$

Mr. Scott A. Smith (*Trans. A. S. M. E.*, vol. x, p. 765) gives it as his opinion that the best belts are made from all oak-tanned leather, and curried with the use of cod-oil and tallow, all

to be of superior quality. Such belts have continued in use thirty to forty years, when used as simple driving-belts, driving a proper amount of power, and having had suitable care. The flesh side should not be run to the pulley face, for the reason that the wear from contact with the pulley should come on the grain side, as that surface of the belt is much weaker in its tensile strength than the flesh side; also, as the grain is hard, it is more enduring for the wear of attrition; further, if the grain is actually worn off, then the belt may not suffer in its integrity from a ready tendency of the hard-grain side to crack. The most intimate contact of a belt with a pulley comes, first, in the smoothness of a pulley face, including freedom from ridges and hollows left by turning-tools; second, in the smoothness of the surface and evenness in the texture or body of the belt; third, in having the crown of the driving and receiving pulleys exactly alike—as nearly so as is practicable in a commercial sense; fourth, in having the crown of pulleys not over ⅛ in. for a 24-in. face—that is to say, that the pulley is not to be over ¼ in. larger in diameter in its center; fifth, in having the crown other than two planes meeting in the center; sixth, the use of any material on or in a belt, in addition to those necessarily used in the currying process to keep them pliable or increase their tractive quality, should wholly depend upon the exigencies arising in the use of belts, and the use of such material may justly be governed by this idea—that it is safer to sin in non-use than in overuse; seventh, with reference to the lacing of belts, it seems to be a good practice to cut the ends to a convex shape by using a former, so that there may be a nearly uniform stress on the lacing through the center as compared with the edges. For a belt 10 in. wide, the center of each end should recede $\frac{1}{16}$ in. As friction is due largely to the unevenness of two surfaces in contact under motion, and as the best tractive quality of belts comes from the evenness and smoothness of the two surfaces of belt and pulley-face, it easily follows that the value of the tractive force of a belt on a pulley face is due, first, to atmospheric pressure; second, to the attractive adhesion of the leather fibers and the oxidized oil of the currying process. The practical effect of a belief in atmospheric aid is to induce the running of belts very or comparatively slack, thus avoiding unnecessary stress on bearings, and maintaining the integrity of belts. A total disregard of this belief has resulted in the destruction of belts in a few weeks or a few months, when they might have served well on toward the full life of the best-made belts, which, as stated, is from thirty to forty years.

Coefficients of Friction in Belting.—In 1882 (*Trans. A. S. M. E.*, vol. vii, p. 349) Prof. S. W. Holman undertook a set of experiments with a view to ascertain the cause of the enormous discrepancy in the results of different experimenters. He caused the pulley to slide under the belt, hanging weights on the loose side of the belt and attaching the other end to a spring balance. He found that, with a low speed of slip, he obtained a coefficient of friction as low as 0·12, while with a speed of 200 ft. per minute he obtained about 0·58, and intermediate values with intermediate speeds of slip; hence, that the coefficient of friction varies with the speed of the slip. It also appears to vary with the pressure, according to the experiments of Mr. Lewis, quoted above. Prof. Gaetano Lanza, in 1884 (vol. vii, p. 350), found the average value of this coefficient under a speed of slip of 3 ft. per minute to be about 0·27, corresponding (if the admissible stress per in. of width be taken at 66⅔ lbs.) to the rule that a belt 1 in. wide must travel 1,000 ft. per minute to transmit 1 horse-power. Mr. H. R. Towne, in 1867, with a slip of 200 ft. per minute, obtained a coefficient of 0·58; but he and Mr. Briggs recommended for use two thirds of this, or 0·42. In discussion of Prof. Lanza's paper, however, Mr. Towne said (vol. vii, p. 359) that his own experiments must now be set aside in favor of those of Prof. Lanza.

Cotton Belts.—Belts made of cotton-duck or canvas are used to a limited extent in the United States. A belt of this kind, tested by Mr. Webber, is described as follows: It was made from cotton-duck folded to make four plies, and then fastened longitudinally with rows of stitches ½ in. apart, the belt then being filled with a composition of boiled linseed-oil and red lead. Another cotton belt (four ply) was made of solid woven cotton, and a mixture of linseed-oil and plumbago worked in and dried under pressure. Powdered soapstone is then used over the surface of the belt on both sides, to prevent its sticking while standing in the roll or coil. It drives well for a time, but stretches a great deal.

"*Cotton-Leather*" *Belts.*—A belt known as the cotton-leather belt is made by the Underwood Manufacturing Company. This belt consists of a firmly woven duck or canvas, which is first stretched by running it at a high speed over pulleys, which are adjustable by means of screws to any required tension, and, after the stretch seems to be thoroughly taken out of it, a thin and soft leather lining is cemented on to one side, under heavy pressure, so as to make a holding surface to be run next the pulleys. The canvas is woven two, three, four, or more "plies" in thickness, and of any desired width.

Hair Belting.—A belt made of woven hair has recently come into use, the claims made for it being that it is stronger and more durable than leather; that it will work in water without injury or softening, and is little affected by heat, steam, or acids, and is more economical in first cost than leather, and can be pieced with or without the use of laces. The Rosendale hair belt, shown in Fig. 1, has what is called an anti-friction edge, which enables the belting to resist the action of strap-forks, and prevents, in a remarkable manner, the edges from fraying. It is claimed that with hair belts the bite on the drums is by friction; the consequent suction between the belt and the drum is thereby dispensed with; hence these hair belts come straight off the drum, and do

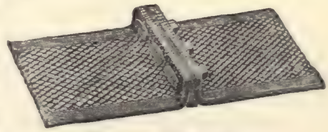


FIG. 1.—Hair belt.

not follow and adhere to it, as in the case of leather. The motion is, therefore, quite steady and uniform.

Bristol's Steel Belt Lacing.—Fig. 2 shows a belt fastening made by punching and bending sheet-steel into the form shown. The cut represents the lacing ready for application, and also shows a finished joint. The lacing consists of a continuous zigzag strip of steel, so proportioned as to give maximum strength with a minimum amount of material. The wedge-shaped points when driven through the belt force the fibers aside without cutting them; hence the ends of the belt are not weakened, as when holes are punched. Bristol's steel lacing, for single-thickness belting, is made in lengths from 1 to 3 in.; for belts wider than 3 in., two or more lacings are used.

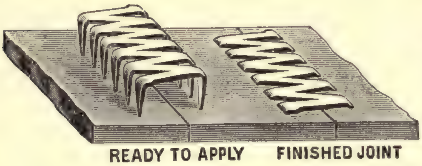


FIG. 2.—Steel belt lacing.

Wire Belting.—A belt made of steel wire woven into a flexible web and covered with rubber is made by the Midgely Wire Belt Company, Beaver Falls, Pa. It is claimed to be nine times as strong as a leather belt, and more flexible.

Leather-Link Belts.—The construction of leather-link belts is shown in Figs. 3 and 4. They consist of small pieces of leather of the oblong shapes shown in Fig. 4, with holes near the ends, by which they are connected. These belts are valuable for a variety of purposes, and especially for damp places. They are water-proof, there being no cemented joints to give way by contact with dampness. By virtue of their weight they are capable of transmitting a considerable amount of power without great width of belt and pulleys. When made with a center-hinge joint they fit laterally to the pulley

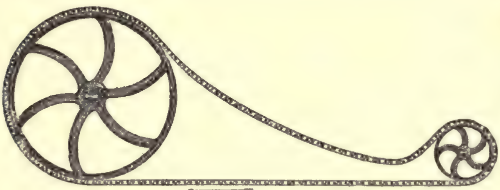


FIG. 3.—Leather-link belt.

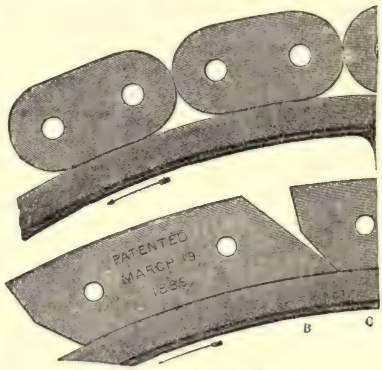


FIG. 4.—Leather-link belt.

more completely than solid leather belts, and this quality assists them in the transmission of power. The proper manner of running a link-belt is illustrated in Fig. 3. Here the belt is drawn taut upon the under side, allowing the upper side to sag and climb the driven pulley, so as to bring the belt in contact with a large proportion of its circumference. This large arc of circumference in contact, and the weight of the belt, result in the largest possible amount of power transmitted. Fig. 5 represents a cross-section of the Acme Link-belt, the dotted lines showing the three bolts by which the links are held together transversely; the three center links, placed upon the highest part of the pulley, as shown, are made V-shaped

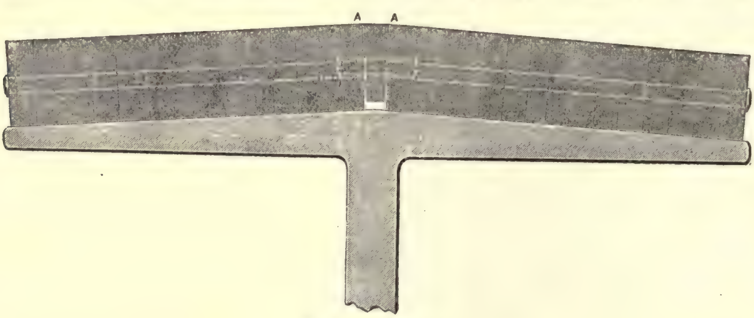


FIG. 5.—Link-belt.

These form the center hinge, giving flexibility and adjustability to the belt. At the lines A A are shown the heads of the two bolts, which extend from this hinge-joint to the outer edge of the belt.

Iron-Link Belts.—Detachable malleable iron links are largely used in bulk-elevating and conveying, and in the transmission of power under suitable conditions. The sizes in common use are designated by numbers—the first or first two figures giving approximately the diameter in sixteenths of an inch of the end and side bars of the link, the final figure indicating sequence of the link among those of like strength; thus, No. 44 has side and end bars $\frac{4}{16}$ in. in

diameter, and is intermediate in other dimensions between No. 42 and No. 45, which are of the same gauge; No. 103 has end-bar $\frac{10}{16}$ in. diameter, and is intermediate in pitch and other measurements between No. 101 and No. 105. The range of regular sizes is from No. 25, $\frac{9}{10}$ in. pitch length and $\frac{11}{16}$ in. wide, with working strength of 75 lbs., to No. 160, $10\frac{1}{4}$ in. long by $9\frac{1}{2}$ in. wide, with working strength of two tons. Tables of "working strains" are published by the manufacturers, and all links are subjected to static test of from two and a half to three times these published strains. For power transmission, particularly at the higher speeds, a larger factor of safety should be used, as high as six being desirable when power and speed require use of the heavier links. The following is a list of usual sizes and working strains published by manufacturers:

Number.	Links per foot.	Working strain.	Approximate in leather belting.	Number.	Links per foot.	Working strain.	Approximate in leather belting.
25..........	10·3	75	1 in. single.	78........	4·6	1.000	10 in. single.
32..........	10·5	150	1¼ "	83........	3	1,200	12 "
33..........	8·6	200	2 "	85........	3	1,300	9 in. double.
34..........	8·6	225	2¼ "	88........	4·6	1,200	8 "
35..........	7·4	250	2¼ "	95........	3	1,600	10 "
42..........	8·8	300	3 "	103........	4	1,800	12 "
45..........	7·4	350	3¼ "	105........	2	1.500	10 "
51..........	10·5	375	2¼ "	106........	2	1.700	11 "
52..........	8	500	4 "	107........	2	1,600	10 "
55..........	7·4	450	4 "	108........	2·55	2,000	13 "
57..........	5·2	600	6 "	109........	2	1,900	12 "
62..........	7·3	650	6¼ "	114........	3·66	2,000	13 "
66..........	6	700	7 "	122........	2	2,200	15 "
67..........	5·2	700	7 "	124........	3	2.500	17 "
75..........	4·6	750	7¼ "	146........	2	2,800	19 "
77..........	5·2	800	8 "	160........	1	4,000	....

The speed consistent with economy and safety is of course largely dependent on varying conditions. Assuming these to be favorable, it has been found that about 300 revolutions of a wheel whose diameter is five times the pitch length of the links should not be greatly exceeded. At low speeds much smaller wheels may be employed, but in no case should a link-belt be run on a wheel of less than six teeth.

Applications of link-belting to other purposes than the transmission of power have led to the designing of various attachment forms. These are inserted in the belts at required intervals, and are employed in elevators, for carrying cups, or buckets, barrel and package arms; in conveyers, for bolting on scrapers or slats; in complete machines, for timed movements; and in numberless other devices for handling materials. Fig. 6 shows one form of standard link and the manner of coupling.

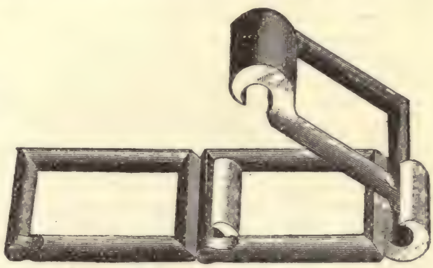


Fig. 6.—Iron-link belt.

Rope Belting, commonly called Rope Driving.—Transmission of power by ropes has recently become quite extensively adopted as a substitute for leather belting or line shafting. The necessity for economy of space in factory-work, the growing tendency toward high speeds in steam-engines, and the employment of electric motors, have created a demand which rope transmission, when intelligently designed and applied, appears to meet more completely than any other connection between the source of power and its application to the work to be done. The special claims for this system, or method, are: That it is positive—no allowances for slip have therefore to be made; cheap—costing much less than leather belting or line shafting, if either the power to be transmitted or the distance between shafts is considerable; noiseless—even at the highest economical speeds; that it does not require rigidly exact alignment of shafts, and is therefore not sensitive to slight settling of buildings; and that it permits changes of direction at will, so that power may be readily carried to any part of the building or plant, and be subdivided in accordance with the requirements of the various machines to be operated. There are two methods of putting ropes on the pulleys: one, in which the ropes are single and spliced on, being made very taut at first and less so as the rope lengthens, stretching until it slips, when it is respliced; the other method is to wind a single rope over the pulley as many turns as needed to obtain the necessary horse-power, and put a tension pulley to give the necessary adhesion and also take up the wear. The essential parts of a continuous rope transmission are the sheaves, the rope, and the tension device. The sheaves, or grooved wheels, are of two forms: one used only for idlers, having a rounded groove, preferably of radius but little greater than that of the rope employed; the other having the V-grooved rim required for driving sheaves. Numerous experiments have been made to determine the best angle for the sides of the grooves in a driving-sheave; and practice still lacks uniformity in this respect, but the most general practice at the present time employs 45°. The bottom of the grooves should be round, and the sides, of course, smooth or polished, to prevent abrasion of the rope. In multiple grooved sheaves it is of vital importance that all the grooves be of exactly equal diameters and angle. If there be any inequality, the rope will travel in the groove of larger diameter at an increased speed, thus causing the

several ropes to pull against each other, and throwing the strain of the transmission on less than the whole number of ropes. Nothing has so militated against the general employment of rope driving in this country as the use of imperfect multiple grooved sheaves, those constructed of wood having proved specially faulty. The unequal density of wood permits unequal wear of grooves, and the sheave soon becomes of differential diameters. The rope generally employed in this country is manilla. Cotton is largely used in England for transmission work, but has not seemed to meet special favor here. Manilla transmission rope should be of long fiber, and be laid in tallow, to reduce the fiber friction caused by the bending of the strands in passing round the sheaves. Such rope tests about as below:

Diameter.	Breaking strain.	Diameter.	Breaking strain.
$\frac{5}{8}$ in.	4,000 lbs.	$1\frac{1}{8}$ in.	12,000 lbs.
$\frac{3}{4}$ in.	5,000 "	$1\frac{1}{4}$ in.	14,000 "
$\frac{7}{8}$ in.	7,400 "	$1\frac{3}{8}$ in.	18,000 "
1 in.	9,000 "	$1\frac{1}{2}$ in.	20,200 "

The above table is based on tests of best long-fiber pure manilla, made specially for transmission purposes. The best practice employs in rope driving but 3 per cent of the ultimate strength, though as high as 6 per cent is figured when conditions are exceptionally favorable. A large margin of safety is required to provide against imperfect splicing.

The tension device—necessary where the continuous wrap system is employed—consists of a movable tension-carriage traveling in suitably constructed ways and carrying an idler sheave, the tension required by the traveling ropes being given by a suspended weight conveniently attached to the carriage. The rope having been wrapped round the driving and driven sheaves the proper number of times for the required driving force, the last strand on the slack side should pass over the tension-wheel (which is deflected to lead the two ends of the rope together), and should not become a direct driving strand until it has passed over the driven wheel. Before reaching the driven wheel this strand may have to pass over idlers or over a groove in the driven wheel itself, but in such cases the groove receiving it should be loose, that the sag may be quickly taken up. As large an amount of the rope as possible should be under the direct influence of the tension-carriage. From 18 to 25 per cent is desirable, though as low as 5 per cent has been found sufficient under certain conditions. The number of driving sheaves over which the rope passes enters into the problem as well as the length of the rope itself. Where the rope passes over four or five sheaves (as in transmitting power to several floors of a building) it is often desirable to employ more than one tension-carriage. The best practice is to use one for every 1,200 ft. of rope, and put not less than 10 per cent of the rope under direct influence of the tension. In direct drives the number of feet of rope may be slightly increased.

The speed of a transmission rope should not exceed 5,000 ft. per minute, as from this point centrifugal force gains so rapidly on the power derived from the increased rope speed that at about 5,500 ft. per minute the power will begin decreasing in the same proportion as its previous rise. Taking C, centrifugal force in lbs.; G, gravity; W. weight of rope per running foot; S, speed of rope in ft. per second, the centrifugal force may be found as follows:

$$C - \frac{W \times S^2}{G}.$$

The wear of rope increases in proportion to the increase of speed: consequently, a velocity of from 2,500 to 3,500 ft. per minute is most efficient and economical. On the size of the sheaves employed depends very directly the life and efficiency of a rope transmission. The diameters should never be less than thirty times the diameter of the rope, and best results are obtained when the sheaves and idlers on the driving side are forty times, and those on the loose side thirty times, the rope diameter. With smaller sheaves the internal friction of the rope fibers is considerable, naturally increasing the wear, and the rope itself, through its stiffness, can not hug the sheaves closely, thus increasing the loss of power due to centrifugal force. Idlers used merely to support a long horizontal span may, if not too far apart, be as small as eighteen diameters without perceptibly injuring the rope. This exception to the rule given above is based on practice, however, and is not theoretically correct. The coefficient of friction of a rope in a 45° grooved sheave has been considered as variable, but several tests recently made where the power transmitted was determined accurateiy by brake-test, and, all conditions taken into consideration, showed this coefficient to vary only from ·33 to ·25. Fig. 7 represents a rope drive recently constructed. The number of wraps of rope depend on the power to be transmitted, are laid in the sheaves of pulleys *a* and *b*. The rope is led from the last sheave on driven pulley *b*, to and over the "idlers" *k* and *l*, to the first sheave on engine pulley *a*. The "idler" *l* is the tension-carriage. The best practice wraps on the rope so that the neighboring ropes are half the length of the rope apart. This is accomplished by starting from the second sheave on *a* to second sheave on *b*, thence to fourth on *a*, etc.; from the last sheave on *b* to the idlers and back to first sheave on *a*, continuing to fill the vacant sheaves to starting-point, where a long splice is made. Fig. 7 shows the method of taking off power at an angle.

C. W. Hunt (*Trans. A. S. M. E.*, vol. xii) gives a calculation of the horse-power of rope drives, from which the following is condensed: C = circumference of rope in inches. D = sag of the rope in inches. F = centrifugal force in pounds. g = gravity. H = horse-power. L = distance between pulleys in feet. P = pounds per foot of rope. Average value

$= \cdot 032\ C^2$. $R =$ force in pounds doing useful work. $S =$ strain in pounds on the rope at the pulley. $T =$ tension in pounds on driving side of the rope. $t =$ tension in pounds on slack side of the rope. $v =$ velocity of the rope in feet per second. $w =$ working strain in pounds. Average value $= \cdot 20\ C^2$. $W =$ ultimate breaking strain in pounds. Average value $= \cdot 720\ C^2$. This makes the normal working strain equal to one thirty-sixth of the breaking strength, and about one twenty-fifth of the strength at the splice. The actual strains are ordinarily much greater, owing to the vibrations in running, as well as from imperfectly adjusted tension mechanism. Assuming that the strain on the driving side of a rope is equal to 200 lbs. on a rope 1 in. in diameter, and that the rope is in motion at various velocities of from 10 to

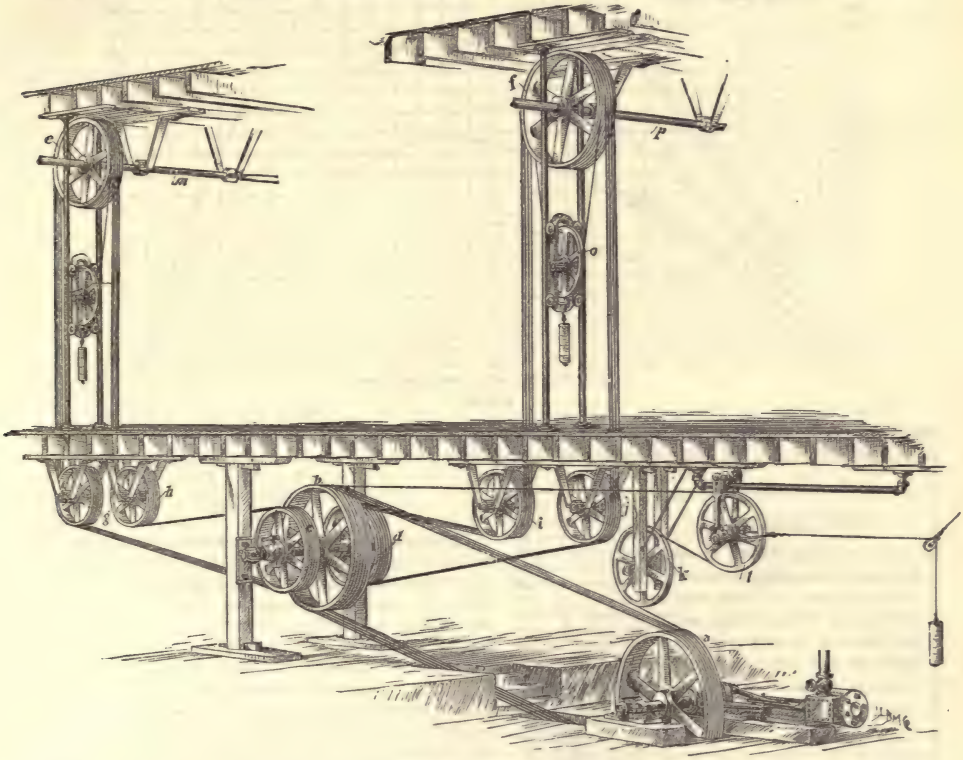


FIG. 7.—Rope-driving.

140 ft. per second. Under this assumption, we will have in all cases a fiber strain of 200 lbs. on the driving side of a 1-in. rope, and an equivalent strain for other sizes. The centrifugal force of the rope in running over the pulley will reduce the amount of force available for the transmission of power. The centrifugal force of the rope is computed by the formula—

$$F = \frac{P v^2}{g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

At a speed of about 80 ft. per second, the centrifugal force increases faster than the power from increased velocity of the rope, and about 140 ft. per second equals the assumed allowable tension of the rope. Computing this force at various speeds and then subtracting it from the assumed maximum tension, we have the force available for the transmission of power. The tension, t, required to transmit the normal horse-power for the ordinary speeds and sizes of rope is computed by formula (4). The total tension, T, on the driving side of the rope is assumed to be the same at all speeds. The centrifugal force, as well as an amount equal to the tension for adhesion on the slack side of the rope, must be taken from the total tension, T, to ascertain the amount of force available for the transmission of power. The tension on the slack side necessary for giving adhesion is taken as equal to one half the force doing useful work on the driving side of the rope; hence the force for useful work is:

$$R = \frac{2\,(T - F)}{3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

and the tension on the slack side to give the required adhesion is

$$\frac{(T - F)}{3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Hence,
$$t = \frac{(T - F)}{3} + F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4).$$

The sum of the tensions, T and t, is not the same at different speeds, as the equation (4) indicates. As F varies as the square of the velocity, there is, with an increasing speed of the

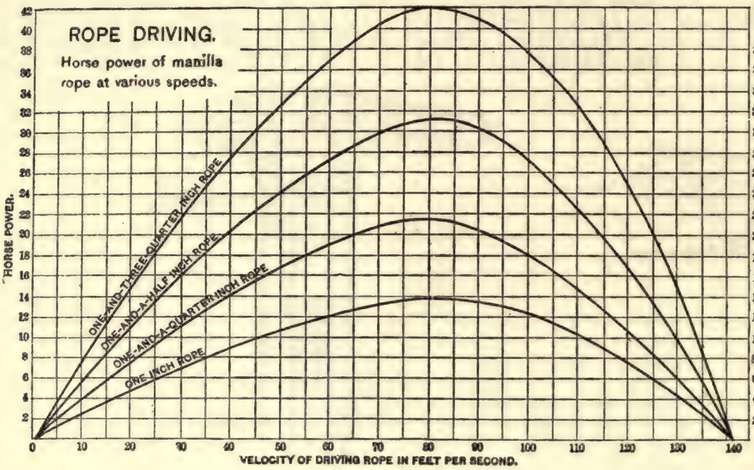


FIG. 8.

rope, a decreasing useful force, and an increasing total tension, t, on the slack side. With these assumptions of allowable strains, the horse-power will be:

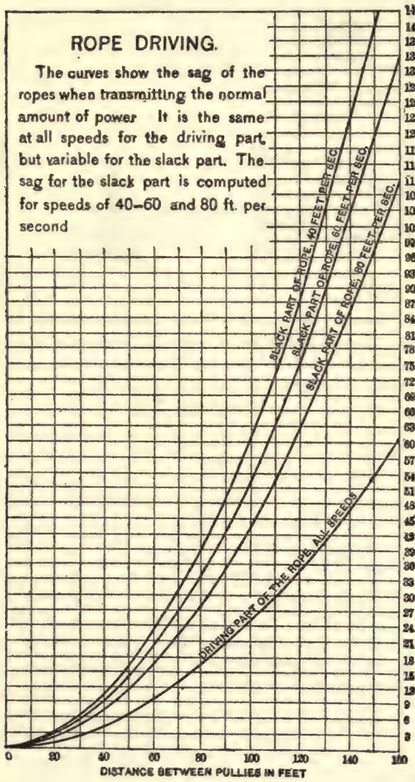


FIG. 9.

$$\text{H.} = \frac{2\,v\,(T - F)}{3 \times 550} \quad . \quad . \quad (5).$$

Transmission ropes are usually from 1 to $1\frac{3}{4}$ in. in diameter. A computation of the horse-power for four sizes at various speeds and under ordinary conditions, based on a maximum strain equivalent to 200 lbs. for a rope 1 in. in diameter, is given in Fig. 8. The horse-power of other sizes is readily obtained from these. The maximum power is transmitted, under the assumed conditions, at a speed of about 80 ft. per second. The first cost of the rope will be smallest when the power transmitted by it is greatest, and under the assumed conditions will be a minimum for a given power when the velocity of the rope is about 80 ft. per second. The deflection of the rope between the pulleys on the slack side varies with each change of the load or change of the speed, as the tension equation (4) indicates. The curves in Fig. 9, giving the deflection of the rope, were computed for the assumed value of T and t by the parabolic formula:

$$S = \frac{P\,L^2}{8\,D} + P\,D.$$

S being the assumed strain, T, on the driving side, and t, calculated by equation (4), on the slack side. The tension, t, varies with the speed, and the curves, showing the sag of the rope in inches, are calculated for speeds of 40, 60, and 80 ft. per second, and for spans commonly used in rope driving. The following table of the horse-power of transmission rope is calculated by formula (5), which makes the total strain on the driving side of the rope, when transmitting the normal power, the same at all speeds, and takes into consideration the effect of the centrifugal force in reducing the driving power of the rope:

Diameter of rope.	Speed of the rope in feet per minute.											Diameter of smallest pulley or idler in inches.
	1 500	2 000	2 500	3 000	3 500	4 000	4 500	5 000	6 000	7 000	8 400	
1/2	1·45	1·9	2·3	2·7	3	3·2	3·4	3·4	3·1	2·2	....	20
5/8	2·3	3·2	3·6	4·2	4·6	5	5·3	5·3	4·9	3·4	....	24
3/4	3·3	4·3	5·2	5·8	6·7	7·2	7·7	7·7	7·1	4·9	....	30
7/8	4·5	5·9	7	8·2	9·1	9·8	10·8	10·7	9·3	6·9	....	36
1	5·8	7·7	9·2	10·7	11·9	12·8	13·6	13·7	12·5	8·8	....	42
1 1/4	9·2	12·1	14·3	16·8	18·6	20	21·2	21·4	19·5	13·8	....	54
1 1/2	13·1	17·4	20·7	23·1	26·8	28·8	30·6	30·8	28·2	19·8	....	60
1 3/4	18	23·7	28·2	32·8	36·4	39·2	41·5	41·8	37·4	27·6	....	72
2	23·2	30·8	36·8	42·8	47·6	51·2	54·4	54·8	50	35·2	....	84

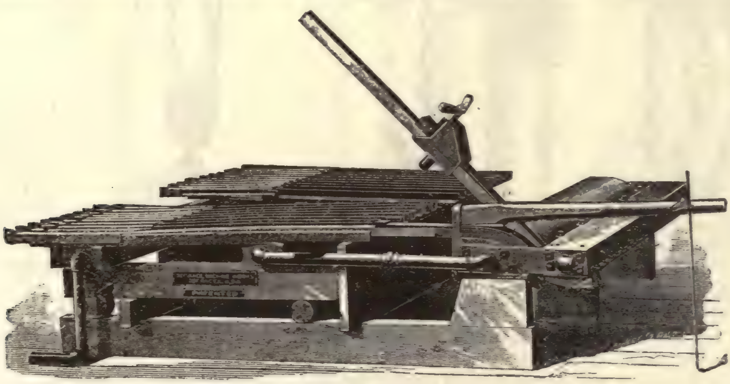
The English rule for diameters of pulleys with cotton rope is from 30 to 36 times the diameter of the rope. For comparison with Mr. Hunt's table, given above, Mr. Webber gives the following figures, taken from an English table, of the power transmissible by a cotton rope at 50 ft. per second, or 3,000 ft. per minute:

	Manilla.	Cotton.
1-in. rope	10·75	10·50
1 1/4 "	17·50	19·50
1 1/2 "	24	30
1 3/4 "	32·50	42

In England, hemp and manilla ropes have been largely superseded by ropes of cotton, the reason assigned being that dry manilla ropes wear out too fast, while the lubricated ones give too low a coefficient of friction.

Bending Machine: see Presses, Forging.

BENDING MACHINERY. It may be taken as a proof of advance in matters mechanical when bent construction is substituted for cut, as, for example, in the making of crank-shafts, in bent-wood furniture, and in machines for making shafts and poles from bent wood. The shaft and pole bending machine shown is for bending double and single bent express shafts and poles, and carriage shafts and poles; forming the heel end of express or carriage shafts and poles, and the body and tip end of shafts complete at the same time. The principle involved is the bending of the material over iron forms which are heated with live or exhaust steam, drying and seasoning the material while under process of bending. Green stock is bent and seasoned at the same time. The machines are furnished in sections. That



Bending machine.

shown in the cut has two sections complete for bending shafts in 10-pair lots, or 18 poles at once: and they can be filled four times per day. The forms are cast with cored chambers at the points of bending, with 2-in.-pipe connections, through which steam is received and discharged to heat the forms. Body-forms are mounted upon rollers with a horizontal attachment for bending shafts of different lengths, and are supplied with adjustable top forms to produce any desired bend on shaft ends. When used for bending poles the rollers under the body-forms are removed and the forms lowered 1 3/8 in., allowing the body of the poles when bent down upon the form to rest upon the top of the ribs, which are used only for giving the side bend to shafts. In operation, the forms are well heated before bending, and the material to be bent is covered with a steel strap which is stretched over the surface of the portion to be bent (by a hand-clamp, as shown by the second shaft in the engraving), to prevent the material being broken while bending. A loop is fitted to the end of each strap, which hooks over a lug cast to the form, and the material is then bent down over the forms and locked by the hand-lever, as shown in the cut. For bending double bends, the loop is held to the lug upon the outside form.

Machines for shop and pole rounding and heel tapering will be found described under molding machinery.

Bicycle: see Cycle.

Bits: see Quarrying Machines.

Blanchard Lathe: see Lathes, Wood-Working, and Hat Machines.

Blast-Furnaces: see Furnaces, Blast. **Stoves**: see Stoves, Hot-Blast.

Blasting: see Quarrying Machinery.

BLOCKS. *Batt's Differential Pulley-Block*, made by the Boston & Lockport Block Co., is shown in Fig. 1. The disk-pulley carrying the hand-chain has cast upon its side a scroll or spiral groove which meshes into the teeth of a wheel placed at right angles to it which carries upon its side the sprocket-wheel for the load chain. The angle of the spiral groove being low, it exerts a powerful purchase on the hoisting wheel. The friction is sufficient to sustain the load.

Alfred Box & Co.'s Double-Screw Hoist is shown in Fig. 2. The power is applied through the chain *g* on the large sprocket-wheel *E*, seen at the left of the cut, which drives a double worm, *C D*, geared right and left into two worm-wheels, *A B*, which also are geared into each other. One of these carries the sprocket-wheel for the hoisting chain *f*. Both chains are always kept in place by the guides.

The Detroit Sure-Grip Tackle-Block is shown in Fig. 3. The brake which will hold the load at any point is simply a wedge that drops by gravity between the upper sheaves. The face of the wedge is fluted to the curve of the rope. The block is made of steel. The arrows in the cut show the direction of the rope through the blocks. It will be noticed that the two center ropes that come in contact with the wedge both travel in the same direction at the same time.

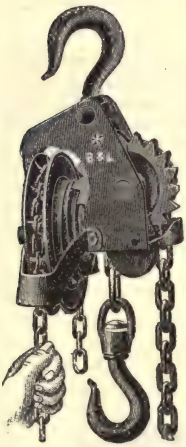


Fig. 1.—Differential pulley-block.

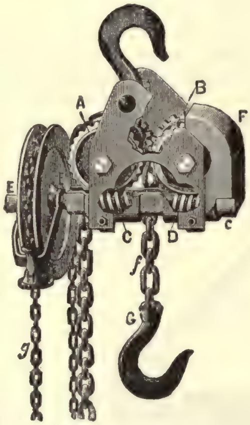


Fig. 2.—Double-screw hoist.

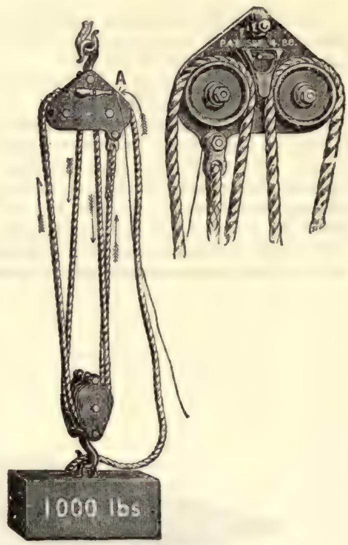


Fig. 3.—"Sure-grip tackle-block.

Weston's Triplex Spur-Gear Block, made by the Yale & Towne Mfg. Co., is shown in Figs. 4, 5, 6, and 7. Figs. 4 and 5 are external views of the block suspended as for use; Fig. 6 is a transverse view, the lower half being shown in section, and Fig. 7 a section showing the hoisting mechanism. All of the mechanism is symmetrically grouped upon a single horizontal axis, and is so arranged as to occupy as little vertical space as possible. Power is applied to an endless hand-chain passing over the pocketed chain-wheel on one end of the central shaft, and is transmitted thereby to the train or spur-gearing contained in the housing on the other side of the block. The main or load chain passes over a pocketed chain-sheave in the center of the block, one of its ends being provided with a suitable hook for receiving the load, and the other being looped up and permanently secured to the frame of the block. Referring to Fig. 6, the hand-wheel at the left transmits power through the central shaft to the steel pinion on its opposite end (seen best in Fig. 7), which in turn engages with the three planet-wheels surrounding it. These latter are of hard bronze, and have cast with them a smaller series of pinions, shown in Fig. 6, which latter engage with the annular gear cast in the stationary frame of the block, as shown in Fig. 7. The three double planet wheels are carried in a frame or cage which supports both ends of each of the pins forming the axis of the wheels. As the central shaft is turned, the whole cage and its three pinions thus rotate slowly within the housing of the block. The inner side of the pinion cage consists of a disk keyed to one end of the steel sleeve forming part of and carrying the hoisting-chain sheave, so that the rotary motion of the pinion cage is thus transmitted to the chain-sheave. The two hubs of the latter are prolonged to form bearings on each side in the frame of the block, and are bored through the center to permit the shaft of the hand-chain wheel to pass

through the sleeve just formed. The mechanism thus described constitutes the entire gearing by which the load is hoisted, and is obviously not self-sustaining. The sustaining mechanism is placed at the hand-chain end of the block (the left of Fig. 6), and consists of a set of brass friction disks, the disks being alternately attached to the central axis and to a ratchet check wheel. The hand-chain wheel is screwed upon the central spindle, as shown, and the construction is such that it is clamped tightly by the friction disks to the shaft either if it is rotated in the direction for hoisting, or if the shaft attempts to revolve in the opposite direction under the pull of the load. The parts being thus clamped together act as one, and the ratchets offer no resistance to the effort of the operator in hoisting. When the direction of the hand-chain is reversed, the alternate disks are released, and the others being held by the ratchets, the load is lowered against their friction at a rate entirely controlled by the move-

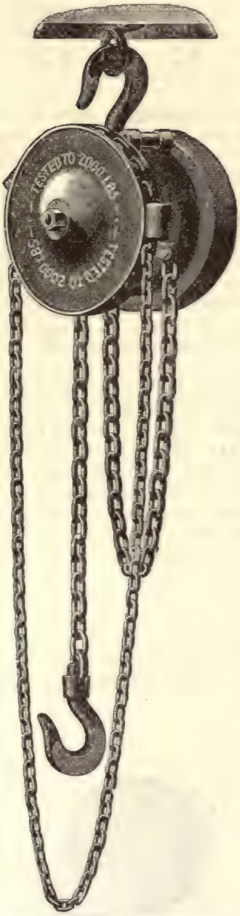


Fig. 4.—Triplex spur-gear.

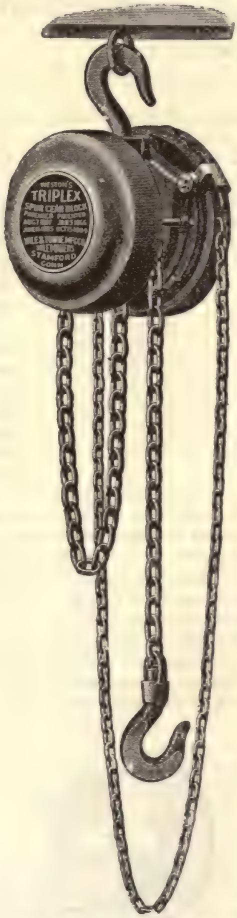


Fig. 5.—Triplex spur-gear.

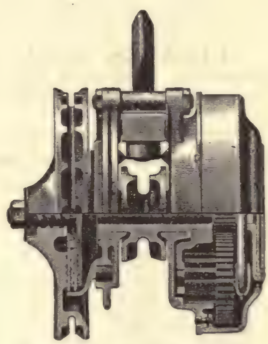


Fig. 6.—Triplex spur-gear.

Fig. 7.—Triplex spur-gear.

ment of the hand-chain, while the stoppage of the hand-chain movement causes the disks to tighten at once and sustain the load. In another form of this tackle a double suspension is employed, two hooks being used, one to sustain the triplex block and the other to carry the chain-tackle. This form is well adapted for use in connection with trolleys for overhead tramrail, or for permanent suspension from fixed eye-bolts, and in some cases its use enables an increase in the available height of hoist to be obtained. In case a powerful block is needed for use on a single occasion, such as the erection of a large engine or other heavy machine, it possesses the advantage that it may be taken apart after the performance of the heavy duty, and the triplex block used alone for subsequent and lighter service.

Efficiency of Chain-Blocks.—Chain-blocks other than the Weston triplex depend upon the friction of the working parts to sustain the load, and for this reason their mechanical efficiency is very low. In the Weston triplex block, as above described, the mechanism is especially constructed so as to reduce friction to a minimum, and therefore it requires a separate attachment for sustaining the load. The following is a record of tests made by Prof. R. H. Thurston, of the efficiency of different forms of chain-block found in the market as compared with the Weston triplex and the old Weston differential:

Comparative Efficiency of Blocks, both in Hoisting and Lowering.

WORK OF HOISTING (LOAD OF 2,000 LBS.).			NUMBER OF BLOCK. ALL BLOCKS OF 1-TON CAPACITY.	WORK OF LOWERING (LOAD OF 2,000 LBS. LOWERED 7 FT. IN EACH CASE), INCLUSIVE OF TIME.	
Actual efficiency. Per cent.	Relative efficiency.	Velocity ratio.		Time in minutes.	Relative efficiency.
79·50	1·00	32·50	1 (Weston's triplex.)	0·75	1·000
32	0·40	62·44	2	1·20	0·186
31	0·39	30	3 (Weston's differential.)	1·50	0·050
28·80	0·36	28	4 (Weston's imported.)	2·50	0·035
26·04	0·33	48	5	2·80	0·380
24·34	0·31	53	6	1·80	0·036
23	0·29	44·30	7	2·75	0·029
18·97	0·24	61	8	3·75	0·018

BLOWERS. (See Air Compressors, Boilers, Steam, and Engines, Blowing.) *Fan-Blowers.*—Fig. 1 shows a type of fan which has come into extensive use for ventilating, drying, and similar purposes where a large volume of air is to be moved at a slight pressure. The shapes of the blades vary in the fans made by different makers. The accompanying table gives the speed, horse-power used, and cubic feet of air exhausted per minute when there is no obstruction, according to the catalogue of the L. J. Wing Co., makers of the fan shown in the cut:

Size.	Revolutions per minute.	Horse-power used.	Exhaust cubic feet of air per minute.
12 in.	1,000 to 2,000	1/16 to 1/4	1,500 to 3,000
18 in.	700 to 1,500	1/8 to 1/2	3,000 to 6,000
24 in.	600 to 1,200	1/4 to 3/4	4,500 to 9,000
30 in.	500 to 1,000	1/8 to 1	7,000 to 15,000
36 in.	400 to 900	3/4 to 2 1/4	12,000 to 26,000
42 in.	400 to 800	1 to 3 1/2	18,000 to 36,000
48 in.	400 to 700	1 4/10 to 5	26,000 to 45,500
54 in.	400 to 600	2 to 5 1/2	32,000 to 48,000
60 in.	400 to 550	2 1/4 to 6	42,800 to 60,000
72 in.	300 to 450	2 1/2 to 6 1/2	45,000 to 67,500
84 in.	250 to 400	3 to 10	56,000 to 89,600
96 in.	200 to 300	3 3/4 to 10	63,000 to 96,500

The Smith Double-Discharge Fan-Blower.—Fig. 2 is a diagram showing the principle of the double-discharge fan-blower in contrast with that of the ordinary fan shown in Fig. 3. To secure the double discharge the case is extended on the rear and a second outlet provided, which is led around under the first to the front, to the two outlets uniting in one at the discharge. The construction is common to both pressure and exhaust fans. The principle is thus described by the makers: It is experimentally demonstrated that the vane of a fan, operating normally, becomes loaded with air in one third of a revolution. In Fig. 3, representing the ordinary single-discharge blower, the compartment *a* is partly loaded, *b* nearly so, and *c* fully loaded. This air it seeks to deliver; but, as there is no outlet, the wheel must drag the accumulated pressure with its accompanying friction around half the circumference of the shell before it can be relieved at *A*. The double-discharge blower is claimed to unload the air at *A* as soon as the full pressure is accumulated, and immediately picks up and discharges another full load at *B* in the same revolution.

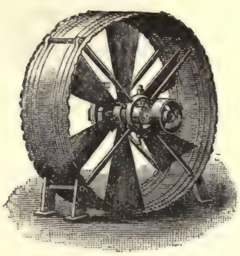


FIG. 1.—Fan-blower.

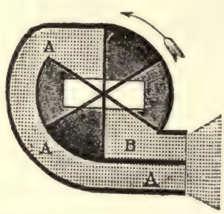


FIG. 2.—Double-discharge blower.

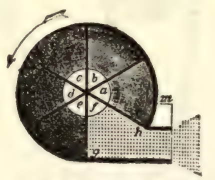


FIG. 3.—Single-discharge blower.

Tilghman's Steam-Jet Exhauster.—The ordinary steam-jet exhauster is such a simple and convenient apparatus that it would be used much more largely than it is—were it not for its wastefulness of steam. It has, however, been noticed that small jets are more efficient than large ones, showing that the surface of contact of the jet with the air is of importance rather than the cross-section of the jet. With the object of increasing this surface of contact, in a new steam-jet exhauster the steam issues radially between two disks fixed at the end of the steam-pipe. Openings through these disks lead into branches connected with the suction-pipe through which the air is drawn. The thin, radial stream of steam in flowing over these openings takes up its full quota of air, and the manufacturers claim that a very considerable saving of steam is effected. The thickness of the jet is regulated by the hand-wheel, the spindle of which is attached to the lower disk. The best distance between these disks is found to be $\frac{1}{100}$ in. to $\frac{1}{50}$ in. The exhauster works with a complete absence of noise. Though

primarily designed for exhausting air for sand-blast purposes, the apparatus is evidently applicable elsewhere.

Boats, Fire: see Engines, Steam Fire.

Bobbin-Holder: see Cotton-Spinning Machinery.

BOILERS, STEAM. During the last ten years no special improvements have been made in the construction of steam-boilers in the direction of improving their economy of fuel; in fact, further progress in this direction is scarcely possible in boilers fired with anthracite coal, since many years ago boilers were made which have given results equal to about 80 per cent of the theoretical efficiency of the fuel. As the chimney gases carry off as a minimum about 15 per cent of the heat of the fuel, and losses due are generally not less than 5 per cent, it is readily seen that the margin left for further saving is extremely slight. As a lb. of pure carbon is capable of generating 14,500 thermal units, equivalent to an evaporation of 15 lbs. of water from and at 212° per lb. of carbon, an efficiency of 80 per cent is equal to an evaporation of 12 lbs. of water from and at 212° per lb. of combustible. How nearly this result has been reached in actual test is shown by the results of the boilers tested at the Centennial Exhibition at Philadelphia in 1876. Out of fourteen boilers tested, the five highest in the list, in order of economy, gave results as follows (Reports of the Judges of Group XX, Centennial Exhibition Reports):

NAME OF BOILER.	Root.	Firmenich.	Lowe.	Smith.	Babcock & Wilcox.	Galloway.
Coal burned per sq. ft. of grate per hour.....	9·76	12·94	7·25	12·96	10·67	10·25
Water evaporated per sq. ft. of heating surface per hour	2·25	1·68	1·87	2·42	1·87	3·63
Temperature of flue gases	393	415	332	411	296	303
Water evaporated per lb. of combustible from and at 212°	12·09	11·99	11·92	11·91	11·82	11·58

These boilers were of different types, as shown in Vol. I of this work.

The Firmenich, Root, and Babcock & Wilcox boilers were of the water-tube type. The Lowe boiler was an externally fired, horizontal tubular boiler of peculiar design. The Smith boiler was a horizontal tubular boiler with a set of water-tube appendages in the furnace, and the Galloway boiler was an internally fired shell-boiler with conical-shaped water-tubes crossing the large internal flue. Results with anthracite coal exceeding 12 lbs. evaporation from and at 212° per lb. of combustible have been frequently reported, but they are scarcely credible, since they would require an efficiency of over 80 per cent, and an allowance for the heat carried off in the chimney gases less than the actual and necessary loss. With semi-bituminous coal, however, containing less than 20 per cent volatile matter, the theoretical heating value being greater than 14,500 heat units, an evaporation of even 13 lbs. from and at 212° is not impossible; but this assumes a perfect combustion of the coal in the furnace, which can scarcely be reached in practice with ordinary boiler-furnaces on account of some of the gases evolved from the coal being chilled by the iron surfaces of the boiler, and therefore escaping unburned. A result of 12·5 lbs. with Cumberland coal is, however, frequently obtained, and this with quite a variety of types of boiler. It may be stated as a general proposition that any boiler, of whatever type (1), in the furnace of which the coal is thoroughly burned with no greater excess of air than is necessary to effect complete combustion, giving consequently the highest practically attainable temperature in the furnace (2), which has its heating surface in a clean condition, so placed as to be completely and uniformly passed over by the currents of heated gases, and (3) sufficient extent of heating surface so that it will absorb all the available heat in the gases above the temperature of the steam, is capable of giving the maximum economical result which can be obtained in the best type of boiler.

This conclusion is also derived from the results of numerous practical tests, as shown in the tests reported by Mr. C. H. Barrus, hereafter referred to. Nevertheless, the average steam-boiler usually gives an economical result far below the maximum, so that possibly 60 per cent of the theoretical efficiency is nearer the average result than 80. This is accounted for by improper construction of the boiler or setting, by unclean surfaces inside and out, by insufficient obstruction in the boiler-tubes and flues to the passages of gas, whereby the latter is "short-circuited," or selects some passages rather than others, as in the horizontal tubular boiler, in which the tendency of the gases is to flow through the upper rows of tubes rather than through the lower, by improper proportions of grate and heating surface for the character of the coal used and for the draft pressure by improper firing, or by leaks of air through the setting. With bituminous coal the difficulty of obtaining maximum economy is greatly increased, on account of the fact that the right kind of furnace for burning such coal under a steam-boiler has not yet been invented. In all parts of the United States west of the Alleghany Mountains there is an enormous waste of fuel constantly going on for this reason. Economy of fuel therefore being independent of the type of boiler, the desirable qualities of boiler which are to be sought for, and which depend largely upon the type, are: safety, low first cost, low cost of maintenance, accessibility for cleaning and for repairs, non-liability to destruction from expansion and contraction and from external corrosion, simplicity of construction, and small space occupied. It is not possible to combine all these desirable qualities in a single boiler; for instance, the boiler of lowest first cost is generally high in cost of maintenance and repairs, and unsafe. In many boilers several desirable qualities are sacrificed to one prerequisite, as portability. A locomotive-boiler is one of the worst possible forms where the

water is impure, but no other boiler can be used on a locomotive. In the attempt to combine as many as possible of these good qualities in a single boiler, and in the fallacious hope of improving on the economy of established types, hundreds of new boilers have been invented during the last ten years, and many put on the market, in which the first principles of good construction are violated. These new boilers, however, generally disappear from the market in a few years, and they do not prevent the course of progress toward the use of a few standard types only, each adapted to certain locations. In these types there is nothing new in general principles of construction, and such improvements as have been made are confined to details.

The common vertical tubular boiler still holds a prominent position, on account of its qualities of economy of floor-space and the first cost. It still also holds its bad pre-eminence as first in the list of dangerous boilers—more explosions of this type being recorded than of any other. Improvements in details in this boiler have been introduced by some makers which tend to render it less dangerous, by providing for complete circulation of the water and giving greater facilities for cleaning.

The common horizontal tubular boiler has not been improved in the last ten years, except in proportions used by some makers. It remains as the most extensively used boiler in the United States, especially for moderate-sized plants, while in Europe it has never obtained much of a footing, being there considered a highly dangerous boiler. In this country its great success has been chiefly due to its low first cost; but it is now becoming less of a favorite, as the water-tube boiler is coming more extensively into use.

The water-tube type of boiler for land purposes has achieved an extraordinary growth during the past ten years, and it gives promise of soon being the most common form of boiler. In Europe its use is still more common than in this country, and the principal boiler exhibits at the Paris Exhibition of 1889 were of that type. Numerous modifications of the type have been brought out by different makers, but the most approved form which is now adopted by several makers in this country consists of a bank of 4-in. water-tubes, inclined at an angle of about 15°, with the horizontal surmounted by one or more horizontal water and steam drums about 36 in. in diameter. At the Philadelphia Exhibition in 1876 several water-tube boilers were shown, but the Babcock & Wilcox was the only one of the particular variety above described. This variety, however, has shown the strongest power of survival, and it is now adopted, as above said, by many makers.

In marine boilers the tendency has been to abandon a great variety of types hitherto used, and to bring into almost universal use the "Scotch" form of boiler, a plain cylindrical shell of large diameter, with two or more furnaces, leading by a vertical passage into numerous horizontal tubes. For large boilers of this type the use of the corrugated furnace-flues has become almost universal. The water-tube boiler of the general pattern used on land has not yet come into any general use at sea, although the Belleville boiler, made in France, has met success in this direction. There has, however, come into use a different type of marine water-tube boiler, in which small tubes about 1 or 1¼ in. in diameter are used with small water-drums or reservoirs, or none at all. The latter form, without drums, is known as the coil boiler. Its sole reason for existence is that it affords the largest amount of heating surface for a given bulk and weight, and is therefore used for torpedo-boats and high-speed steam-launches. The other form with water-drums approaches more nearly to the land type of water-tube boiler, and in it efforts are made to combine the desirable features of the coil boiler with the steady water-level, accessibility for repairs, and general durability of the ordinary form of water-tube boiler. Several such boilers are now in use on steam-yachts, and it is proposed to use them on large ocean-going vessels, but it is too early yet to say whether any of the forms will prove permanently successful. The increase in steam pressures carried in ocean vessels in recent years, up to 160 lbs. or more, makes it necessary that the Scotch form of boiler shall be built of steel plates over 1 in. in thickness. This, with its great diameter, makes it an exceedingly heavy, bulky, and costly boiler for the power it develops; and there is great need for the introduction of a new type of boiler which shall admit of the still higher pressures now desired, and be lighter and more economical of room than the present form. It is probable that some form of water-tube boiler will soon be introduced to meet these requirements.

The most important general change in the construction of boilers in recent years has been the almost complete substitution of soft steel plates for the wrought-iron plates formerly used. The use of steel for steam-boilers dates back to 1856 in England and 1862 in the United States, but it required many years to bring it into general employment. The objections to it when first introduced were that it was made too high in carbon and phosphorus, the necessity for making the steel very soft then not being understood, consequently cracked sheets were very common, and also that it was high-priced. With the introduction of the open-hearth process in France about 1867 and in the United States in 1869, a softer grade of steel was made, which, after it was learned that low phosphorus as well as low carbon was necessary for good boiler-plate, became entirely successful, and better in quality than the best boiler-iron. The improvements in steel furnaces and plant have recently greatly cheapened the cost of steel boiler-plate, so that it can be made at a much lower cost than even ordinary grades of boiler-iron, and it has therefore practically driven the latter out of the market. The quality of steel desired for boiler and fire-box plates may be seen from the following specifications given by different authorities:

United States Navy.—Shell: Tensile, 58,000 to 67,000 lbs.; elongation, 22 per cent in 8 in. transverse section, 25 per cent in 8 in. longitudinal section. Flange: Tensile, 50,000 to 58,000 lbs.; elongation, 25 per cent in 8 in. Chemical requirements: Phosphorus, not over

·035 per cent; sulphur, not over ·040 per cent. Cold-bending test: Specimen to stand being bent flat on itself. Quenching test: Steel heated to cherry red, plunged in water 82° F., and to be bent around curve one and a half times thickness of the plate.

British Admiralty.—Tensile, 58,240 to 67,200 lbs.; elongation in 8 in., 20 per cent. Same cold-bending and quenching tests as United States Navy.

Bureau Veritas.—Shell: Tensile, not less than 60,480 lbs.; elongation in 8 in., 20 per cent; must withstand after heating to dull red, and being plunged into water of 80° F., being bent until opening between ends is three times thickness of plate.

United States Revenue Marine.—Tensile, not less than 60,000 lbs.; reduction of area, 50 per cent.

American Boiler-Makers' Association.—Tensile, 55,000 to 65,000 lbs.; elongation in 8 in., 20 per cent for plates $\frac{3}{8}$ in. thick and under; 22 per cent for plates $\frac{3}{8}$ in. to $\frac{3}{4}$ in.; 25 per cent for plates $\frac{3}{4}$ in. and over. Cold-bending test: For plates $\frac{1}{2}$ in. thick and under, specimen must bend back on itself without fracture; for plates over $\frac{1}{2}$ in. thick, specimen must withstand bending 180° around a mandril one and a half times the thickness of the plate. Chemical requirements: Phosphorus, not over ·040 per cent; sulphur, not over ·030 per cent.

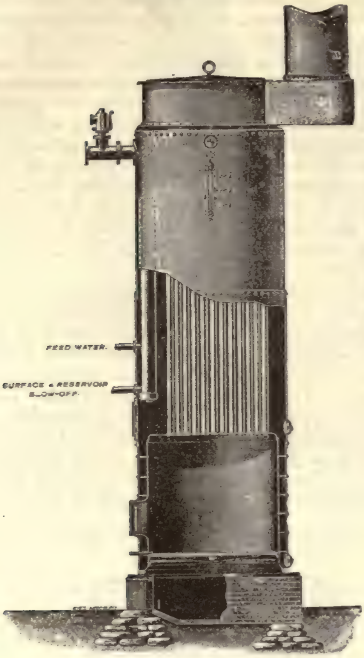


Fig. 1.—Reynolds boiler.

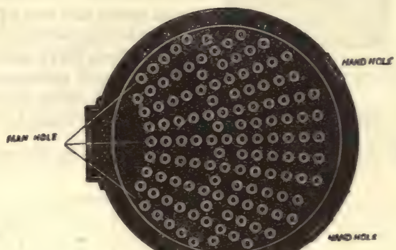


Fig. 2.—Reynolds boiler.

Fire-Tube Boilers.—*The Reynolds Vertical Tubular Boiler*, made by the E. P. Allis Co., of Milwaukee, is shown in Figs. 1 and 2. The tubes are set in rows radiating from a large man-hole located over the fire-door and bottom tube-sheet, consequently every flue and all parts of both tube-sheets can be inspected and cleaned when the man-hole cover is removed. Hand-holes are located near the man-hole for admitting light for inspecting and inserting a hose-nozzle for washing the tubes and crown-sheet. Hand-holes are placed at intervals around the base, where sediment collected in the water-legs may be removed. The feed-water is pumped into the internal reservoir through the feed-pipe; this reservoir being closed at the bottom. The discharge into the boiler is over the top, and it being so much larger than the feed-pipe, the current upward is very slow, consequently the feed-water gains the same temperature as the water in the boiler before it is discharged into the boiler. This action is effective in precipitating nearly all of the heavy impurities carried in with the feed-water, which can be blown out of the reservoir by a blow-off arranged for this purpose. By carrying the water in the boiler slightly above the top of the reservoir, it can then be utilized as a surface blow-off to free the boiler of scum or light impurities collected on the surface of the water. The smoke-hood on top of the boiler is furnished with a revolving top having a removable cover. For the purpose of cleaning the flues this cover is removed, and only a small portion of the total number of flues are exposed at one time; this arrangement enables the fireman to clean the flues while the boilers are in operation. This type of boiler is especially adapted to locations where floor-space is valuable, as from 300 to 400 horse-power of vertical boilers can be located in the space required by an ordinary horizontal tubular boiler of 100 horse-power capacity.

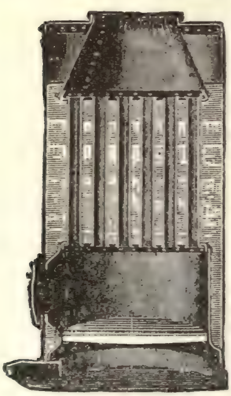


Fig. 3.

Vertical Boiler with Submerged Tubes.—Fig. 3 represents a vertical tubular boiler, built by the Morrisville Machine Works, Baldwinsville, N. Y. The upper ends of the tubes are submerged in water, and are thereby prevented from burning out, obviating one of the principal defects of the ordinary vertical boiler.

Payne's Vertical Tubular Boiler.—The boiler shown in Fig. 4, built by B. W. Payne & Sons, Elmira, N. Y., is also designed to prevent the burning out of the upper ends of the tubes. Midway between the outer tubes and the shell of the boiler is suspended a cylindrical baffle-plate—concentric with the boiler-shell. This baffle-plate, or apron, extends from about

$1\frac{1}{4}$ in. below the upper head to within about 10 in. of the bottom of the water-leg of the boiler, and completely surrounding the tubes. Midway between this apron and the boiler-shell is suspended from, and joined to, the upper head a perforated plate, which extends downward about 20 in., encircling the apron. The effect produced by the apron and perforated plate is that when the boiler is subjected to heat from its furnace, the water surrounding the tubes ascends and is replaced by the cold water from the space between the apron and the boiler-shell. As the heat increases, the circulation around the apron becomes more rapid, the water within the apron and around the tubes being forced to and over the top of the apron where the separation of water and steam takes place; the latter passing through the perforated plate to the space between the boiler-shell and that plate, and the former descending to the water contained between the apron and boiler-shell. The steam is drawn from the boiler through an opening in the shell near the upper head. The separation of the water and steam is thorough, as the water after passing over the apron has a downward tendency, which, with its greater weight, causes it to descend; while the steam readily passes through the perforated plate, and is found in the outer space free from entrained water.

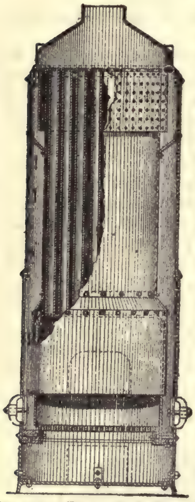


FIG. 4.—Payne's boiler.

Marine Boilers with Corrugated Flues.—Nearly all ocean-going steamers are now fitted with boilers of the Scotch type. Two of these boilers are shown in Figs. 5 and 6. These boilers were made by Messrs. J. & G. Rennie, of London. The use of corrugated furnace-flues, or of some substitute for them, as flues with stiffening ribs, has become almost universal since the use of high pressures of steam 100 lbs. and upward. The marine boilers used in the United States gun-boats Yorktown, Concord, and Bennington, have each three corrugated furnace-flues leading into one common back connection. From here the products pass along through the nest of tubes to the chimney. The British Board of Trade in 1891 adopted a new formula for the working pressure allowable on corrugated furnaces, as follows: $WP = \frac{14000 \times T}{D}$, in which WP is the working pressure in lbs. per sq. in., T thickness in

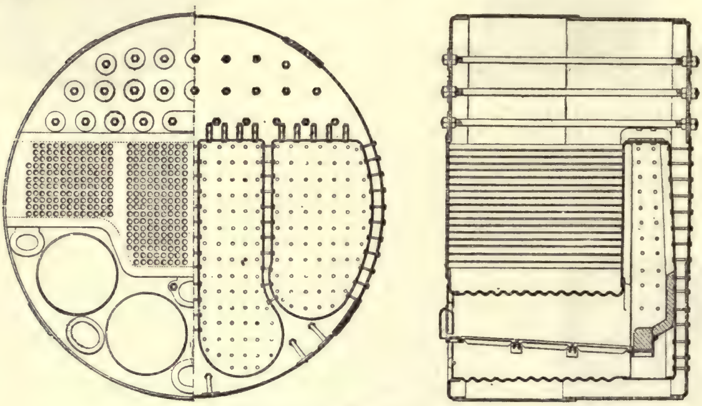


FIG. 5.—The Rennie boiler.

in., and D mean diameter in in. Lloyd's Registry have also adopted a new formula, as follows: $WP = \frac{1234 \times T^2}{D}$, in which T is the thickness in sixteenths of an in., and D the greatest diameter in in.

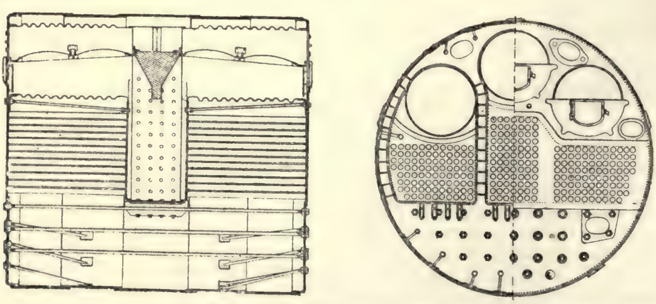


FIG. 6.—The Rennie boiler.

SEMI-PORTABLE BOILERS.—*The "Economic" Boiler.* The boiler shown in Fig. 7 is made by the Erie City Iron Works, Erie, Pa. It has been given the trade name of the "Economic."

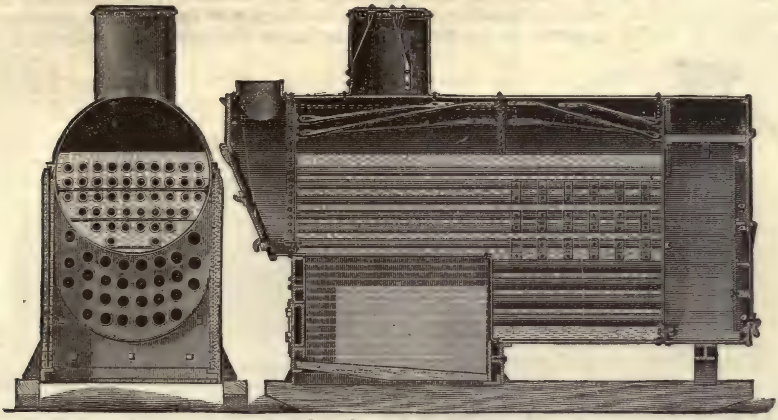


FIG. 7.—The economic boiler.

The front end of the boiler is cylindrical in form and extends over the furnace, forming the crown-sheet. The rear end is oval, the lower portion extending below far enough to hold the short tubes leading from the furnace to the back connection. The furnace is brick-lined, and can be detached when desired. The fire-brick are held in place by iron rods, which are protected from the fire and can be removed and replaced when necessary. The cylindrical crown-sheet gives a large effective heating surface, and is always fully protected by water. There are no water sides to fill with sediment, and the fire-brick lining of the furnace insures a very high degree of temperature and combustion of the gases, and consequent economy in fuel.

The "Economizer" Boiler.—Another semi-portable boiler, known as the "Economizer," made by the Porter Mfg. Co., Syracuse, N. Y., is shown in Fig. 8. It is largely used for

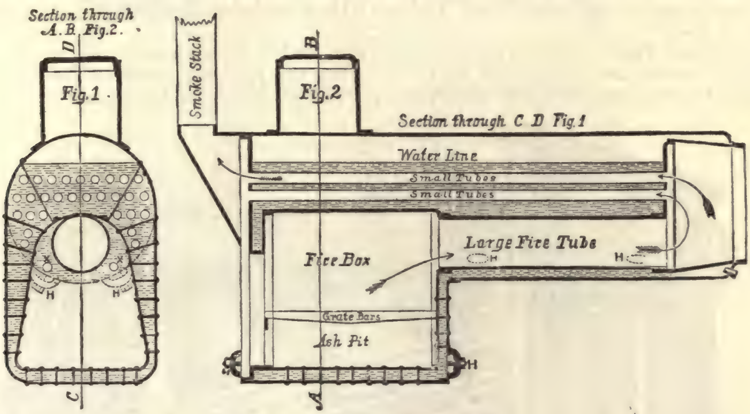


FIG. 8.—The economizer boiler.

agricultural purposes, with wood or straw for fuel. The large fire-flue answers the purpose of an enlargement of the fire-box. The flame passes into it bodily, thus enabling the gases to become ignited before passing into the small return tubes. The fire is entirely surrounded by water, even the front itself being heating surface. The combustion chamber is surrounded by a water-jacket. It emits very few sparks; the returning of the flames through the small tubes compels the deposit of the great body of sparks in the chamber at the rear.

WATER-TUBE BOILERS.—*The Heine Water-Tube Boiler* (Fig. 9).—The distinguishing features of the Heine boiler as compared to other water-tube boilers are briefly these: 1. It is an entirely riveted construction, with no bolted joints to work loose. 2. While it has the same principle of action as other water-tube boilers, viz., a rising current of steam and water mixed in front, and a falling current of solid water in the rear, it differs from them in having the throat opening from 65 to 90 per cent of the total cross-sectional tube area. 3. The travel of the gases is horizontal with a gradual upward trend, as distinguished from the up and down travel of the gases in the older types of water-tube boilers. 4. The water-legs being the strongest parts of the boiler, form its natural supports, the front one resting on a fixed fire front, the rear one on expansion rollers on the rear wall. 5. The internal mud-drum

(inclosed inside of the steam and water drum) forms a receptacle in which the feed-water is gradually heated to approximately the temperature of the water in the boiler, and as it issues from the front top of the same in a thin current, it mixes with the main current flowing backward in the shell, and the expansion strains from changes in temperature are practically eliminated. 6. Access is given to the outside of the tubes through hollow stay-bolts in the

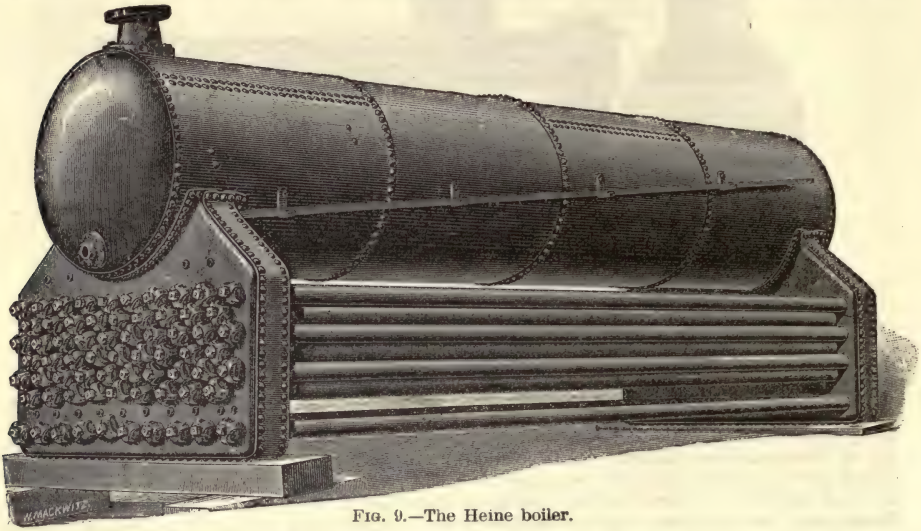


FIG. 9.—The Heine boiler.

water-legs at all times, so that the tube-heating surfaces can be inspected, cleaned, and watched while the boiler is under steam. 7. All the hand-hole plates opposite ends of tubes have internal joints, thus doing away with the danger resulting in other types from broken bolts in the headers. 8. The mode of setting practically prevents the flame or hot gases from striking the riveted work of the shell, until their temperature has been reduced to about 900° F., or less.

Gill's Water-Tube Boiler.—The Gill boiler, Fig. 10, is a representative of a number of new water-tube boilers that have come into use during the past ten years, of the general type which has become standard, and apparently permanent, having a horizontal drum in which

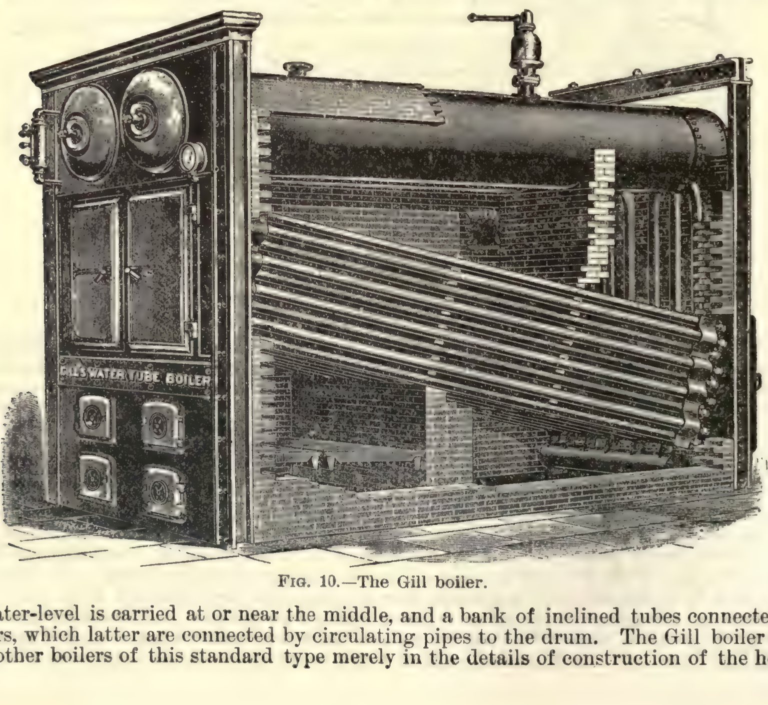


FIG. 10.—The Gill boiler.

the water-level is carried at or near the middle, and a bank of inclined tubes connected with headers, which latter are connected by circulating pipes to the drum. The Gill boiler differs from other boilers of this standard type merely in the details of construction of the headers,

and in its method of connecting the headers to the drum. These details are shown in Figs. 9 and 10. The water-tubes, 4 in. in diameter and spaced about 3 in. apart, are inclined at an angle of about 15° from the horizontal. Each nest of 4 or 5 tubes is expanded into a cast-iron box or header at each end in such a way that the tubes are staggered instead of being placed one above the other. By thus making these boxes short, and by connecting them by slightly flexible tubes, the danger of breakage is entirely avoided, which is of common occurrence where the headers are made in one long cast-iron box. The connection between the headers and the steam and water drum overhead is exceedingly simple, consisting of short tubes which are expanded into the top of the headers and into the drum entering the latter radially, for which purpose they are curved to the proper form. Fig. 11 shows a bank of headers and a steam-drum with their connections.

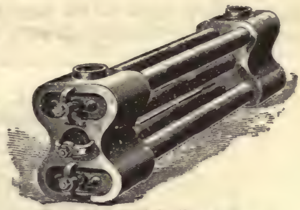


FIG. 11.—Gill boiler tubes.

Yarrow's Water-Tube Boiler.—Fig. 12 shows a type of water-tube boiler which has been lately introduced by Messrs. Yarrow & Co., for use in the torpedo-boats built by this firm. There is a horizontal upper chamber or receiver and two lower chambers, each of the latter occupying the space at the sides of the fire-grate. The receiver is connected to the lower chambers by numerous straight lengths of pipe, composed of weldless-steel tube. The parts of the chambers into which these tubes are inserted are flattened so that several rows of the tubes are possible. The tubes are expanded into the chambers in the ordinary way. Each chamber is made in two parts, which are flanged out and joined by nuts and bolts, a copper wire serving as packing to make a steam-tight joint. The water-gauge glasses and other fittings are attached to the upper cylinder. The whole is inclosed by a smoke-jacket, and the products of combustion pass upward among the tubes to the uptake on the top of the boiler. The length of the cylinders is about 6 ft., and the diameter of the top

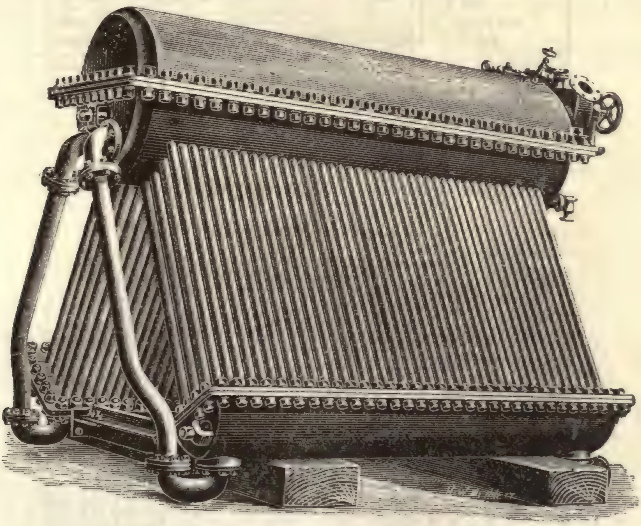


FIG. 12.—The Yarrow torpedo-boat boiler.

receiver is 20 in. The tubes are galvanized, and arrangements have been made whereby the whole of the boiler can be galvanized complete. When running, the water-level is kept about half-way up the receiver. The advantages claimed for the boiler are that it is free from complicated and intricate parts, there being neither bends, elbows, nor intermediate obstruction to the free flow of steam and water through the tubes.

The Cowles Water-Tube Boiler.—The Cowles boiler (Fig. 13) is one of a numerous class of boilers recently designed to combine great steaming capacity, at the highest steam pressures, with the minimum weight of structure and water contained, and minimum space occupied. Obviously this combination can be obtained to the highest degree in what is known as a coil-boiler, which consists of simply a mass of coils of iron or copper tubes of small diameter, and a furnace underneath them. Such coil boilers, however, are usually defective in durability, and are apt to produce steam of varying quality, sometimes wet and sometimes superheated to a higher degree than is desirable. The coil boiler has therefore been modified in the direction of the water-tube boiler, supplying it with one or more water and steam drums; and while retaining the small diameter of tubes, they are not made into continuous coils, but are made in separate short lengths, each of which is connected with the water-drums, and is easily replaceable in case of burning out. The chief field for boilers of this kind is in marine work, where high speeds and light weight are required, especially in torpedo-boats and in racing yachts. Several varieties of this type of boiler have been built, as the Thornycroft, Herreshoff, Ward,

Mosher, and Cowles. Detail drawings of some of them, and records of tests made by engineers of the U. S. Navy, are given in the Report of the Chief of the Bureau of Steam-Engineering for 1890. The Cowles boiler is selected here as a representative of the general type. It is described as follows by its patentee, Mr. William Cowles, of Brooklyn, N. Y., and consists of a rectangular grate and ash-pan, over which is set horizontally a cylindrical shell for steam and

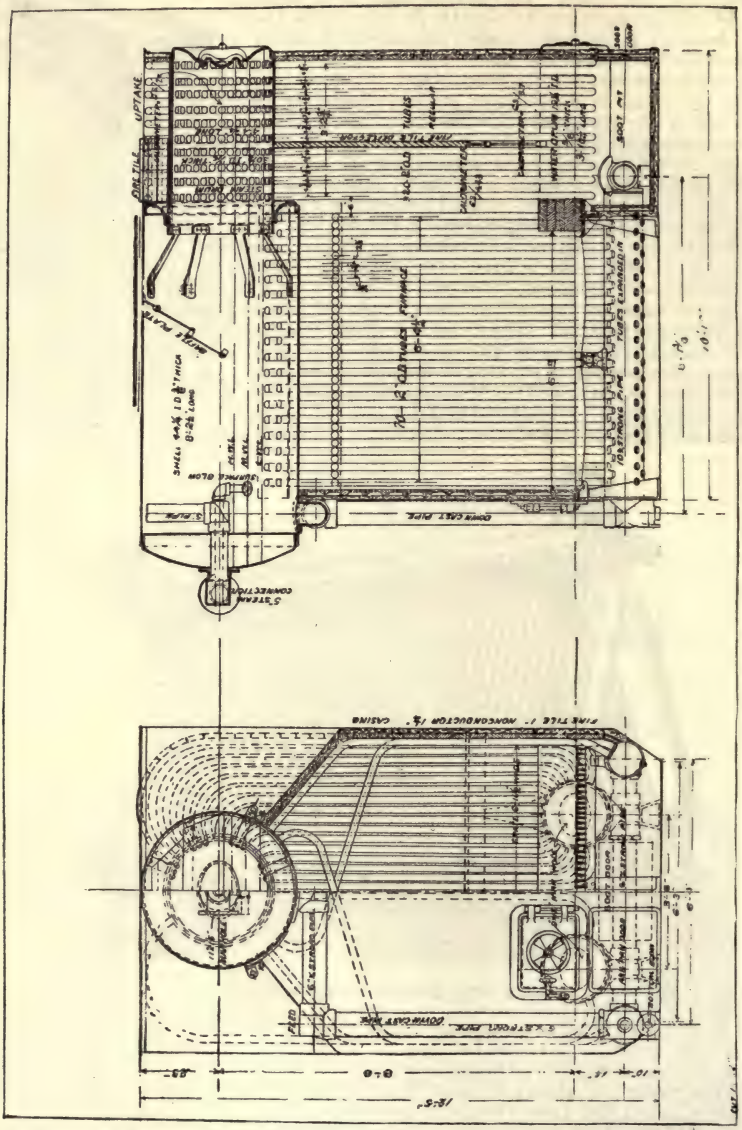


FIG. 13.—The Cowles boiler.

water; from the back part of this shell a steam-drum projects back horizontally; from its front end large "downcast" pipes extend down to large side pipes at each side and below the furnace; these side pipes connect at their back ends with the water-drums lying horizontally back of the furnace and below or at its level; numerous bent water-tubes, with ends expanded in, extend vertically and connect between the water and steam drums and between the side pipes and shell. The whole is inclosed in a suitably lined casing for marine use and in masonry for stationary work.

Mosher's Water-Tube Boiler.—Figs. 14, 15, 16, and 17 illustrate the boiler designed by Mr. C. D. Mosher for the fast steam-launch Norwood, owned by N. L. Munro, of New York city. It has several novel features. For the power the boiler has to furnish, it occupies but a very small space, and its center of gravity is very low. It has 26 sq. ft. of grate surface, and about 1,000 sq. ft. of heating surface. The tubes are made of steel, 1 in. diameter, solid drawn. The weight of the boiler and water is $2\frac{1}{2}$ tons; its length is 7 ft. 3 in.; breadth, 6 ft.; total

height, 3 ft. 6 in. Fig. 14 represents an end elevation of the boiler; a portion of the casing is removed to show the interior. Fig. 15 represents a horizontal section taken on line 2, 2, Fig. 16. Fig. 16 represents a transverse section on line 3, 3, Fig. 14. Fig. 16 represents a vertical section on line 4, 4, Fig. 16. The same letters of reference indicate the same parts in all the figures. In these illustrations *a a* represent two horizontal water-drums, which are arranged parallel with each other at opposite sides of the furnace *b*; these drums are placed just above the grates *c*. The furnace, as will be seen by referring to Figs. 14 and 15, is divided into two sections by an intermediate water-drum a', and a row of tubes, f^2, extending upwardly from the drum a', and arranged so that above their bent ends they form a close wall extending lengthwise of the furnace; the upper portions of the tubes f^2 are curved outwardly; every alternate tube extends over to the steam-drum at the one side of the furnace, and the remaining tubes over to the steam-drum at the other side of the furnace. The intermediate drum a' is connected by transverse pipes a'' with the outside water-drum *a a*, so that water from the drums *a a* enters the drum a', and passes upwardly therefrom through the tuebs f^2. The tubes f^3 are connected with the transverse tubes a''; they extend upward, and are bent at their upper ends, and joined to the steam-drums *d d*. These tubes, f^3, spring from the pipes a'' in two rows. Those of the outer row are bent inwardly, as shown at 14, Fig. 17, so that the tubes f^3 constitute closed vertical end-walls, the front one being interrupted by the spaces for the fire-doors. The steam-drums *d d* are placed above the water-drums *a a*, and are practically outside the space which constitutes the furnace. They are arranged to bring their outer sides in a vertical plane with the outer sides of the water-drums to accommodate the casing *e*, which incloses the whole apparatus. Each water-drum is connected with the steam-drum by a series of bent steam-generating tubes, f, f', f^4, f^5. From the points of connection with the water-drums, these tubes are bent inwardly and upwardly toward the center and upper portion of the furnace. They are then bent outwardly until they join the inner sides of the steam-drums.

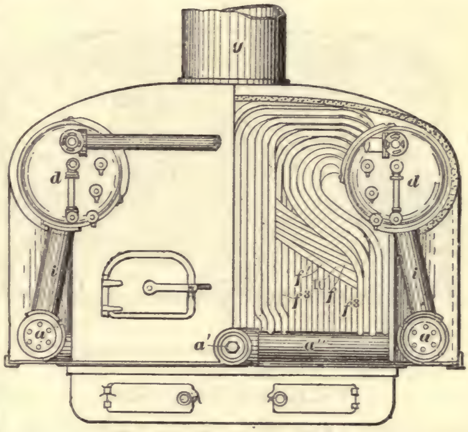


FIG. 14.—The Mosher boiler.

It will be seen that the tubes f, f', f^4, f^5, are formed and arranged to expose their contents in a favorable manner to the heat of the furnace, and at the same time enable the steam-drums *d* to be located at a minimum height above the water-drums *a*, thus giving the generator a low center of gravity, and making it in this respect desirable for steam launches and yachts, in which economy of vertical space is desirable. The arrangement of the inner tubes *f* is such that these tubes along the forward portion of the furnace, or fire-door end, nearly to the opposite end, constitute a practically closed wall, made up of the inclined portions of the tubes. The lower end of every alternate tube *f* is bent, as shown at 8, Fig. 16, so that the whole form two inner rows at the points where they join the water-drums, and come in close contact with each other just above the bend 9. The object of arranging the tubes to form a close wall, as described, is to cause the heated products of combustion to pass from the front toward the rear end of the furnace before passing to the outside of these tubes. To enable the products of combustion to pass to the outside of the tubes, a number of these tubes at the rear end of the furnace are made straight, as shown at f', in Figs. 14, 16, and 17, creating the spaces 10 between the tubes f' and the intermediate tubes *f*. The spaces 10 permit the products of combustion to pass outwardly, as indicated by the arrows in Fig. 17, into the rear portion of the space between the walls composed of the tubes *f* and an outer wall composed of the tubes f^4, placed next to

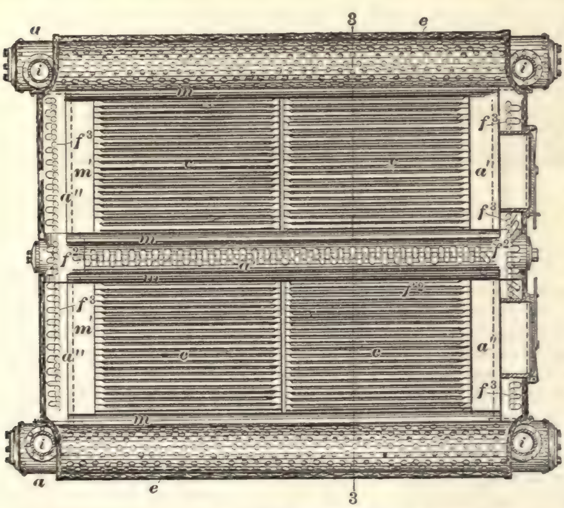


FIG. 15.—The Mosher boiler.

the inner casing k. The lower ends of the tubes f^4 are marked 12, 13, in Fig. 16. The wall composed of the tubes f^4 extends the entire length of the furnace. The spaces between the inner and outer walls of tubes contain the tubes f^5, which are of the same general form as the tubes f and f^4, but are separated, so that the products of combustion pass freely around each tube. With this arrangement the steam-drums are protected from the direct action of the fire by the interposed tubes, and can be affected only by the radiation of heat from the hot gases that pass through the spaces 10 at the rear portion of the fire-box; hence, the liability of burning or injuring the drums by overheating is reduced to a minimum. As an additional protection to the steam-drums, the partitions k k, previously referred to, are interposed between the lower portions of the steam-drums and the furnace; these partitions lie close to the wall formed by the tubes f^4, as shown in Fig. 16.

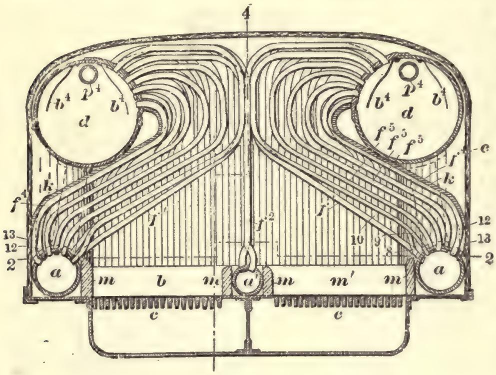


FIG. 16.—The Mosher boiler.

The smoke-stack g is placed over the forward end of the furnace, as shown in Fig. 17, causing the products of combustion, after passing through the spaces 10, to travel in the opposite direction toward the forward end of the furnace, as indicated by the dotted arrows in Fig. 17, the tubes being thus exposed to the action of the heat. This arrangement is another important feature of the invention. A baffle-plate or deflector, h, is placed across the upper portion of the furnace, just in the rear of the smoke-stack, as shown in Fig. 17, which causes the products of combustion to take a downward course, as indicated by the dotted arrows, before reaching the smoke-stack, and prevents the too direct escape of the products of combustion, and causing the same to act more fully upon the water in the tubes. The products of combustion pass to the stack through the openings formed between the tubes f and f^2, the latter being raised above the tubes f forward of the deflector h, as shown in Fig. 17, leaving spaces between the horizontal portions of the tubes f and f^2 of sufficient width to permit the passage of the smoke and gases to the stack. The ends of the steam-drums are connected with the ends of the water-drums by the pipes i for the return of water from the steam-drums to the water-drums. These return pipes are located outside of the casing e, as is shown in Fig. 15, and are not subjected to the heat within the casing; hence the descent of water through the return pipes to the water-drums is facilitated. Baffle-plates b^4, b^4, shown in Fig. 16, are attached to the upper portions of the steam-drums at opposite sides of the perforated dry-pipes p^4, which extend through the drums, and are connected outside of the drums with pipes which conduct the steam to the engine. The water-drums are protected from contact with the fuel by the fire-brick linings m, and the transverse connecting pipes a'' are protected by similar linings, m'. The water-drums act also as mud-drums, and have suitable blow-off cocks and hand-holes to allow the removal of the deposits. The tubes f, f', f^2, f^3, f^4, f^5, are expanded in the drums and pipes by special tools devised for this purpose. The adoption of two steam-drums, d, not only makes the boiler symmetrical, but it gives a greater height of furnace in proportion to the total height of boiler than could be obtained with one drum; and the water capacity is increased so that a sudden lowering of water-level in the boiler when the supply of feed-water is interrupted is prevented.

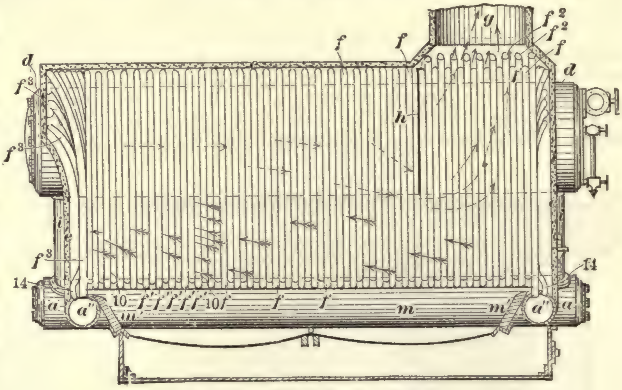


FIG. 17.—The Mosher boiler.

Non-conducting Coverings for Boilers, etc.—W. Hepworth Collins, in *Engineering*, Sept. 4, 1891, describes some experiments he made on different non-conducting coverings for steam-boilers. A mass of each material to be experimented upon, 1 in. thick, was carefully prepared and placed on a perfectly flat iron plate or tray, which was then carefully maintained at a constant temperature of 310° F. The heat transmitted through each non-conducting mass was calculated in pounds of water heated 10° F. per hour. The following table gives the results:

SUBSTANCE, 1 IN. THICK (IN MASS); HEAT APPLIED, 310° F.	Pounds of water heated 10° F. per hour through 1 sq. ft.	Solid matter in 1 sq. ft. 1 in. thick. Parts, 1,000.	Air included. Parts, 1,000.
1. Hair felt	11·4	189	957
2. Cotton felt	10·6	75	930
3. Jute felt	13·2	162	921
4. Linen felt	11·7	64	753
5. Loose cotton felt	9·3	17	990
6. Carded cotton	8·1	16	987
7. Rabbit-hair "wool"	7·1	43	912
8. Poultry feathers	6·2	44	976
9. Cork powder	13·6	66	931
10. Sawdust powder	14·2	141	793
11. Asbestus powder	47·9	67	961
12. Fossil meal	52·1	78	910
13. Plaster-of-Paris	36·2	371	598
14. Calcined magnesia	14·7	24	979
15. Compressed calcined magnesia	53·4	291	711
16. Fine sand	66·3	533	473

The following table shows the results of practically treating the several non-conducting mixtures on a 5-in. steam-pipe:

PREPARED MIXTURES FOR COVERING STEAM-PIPES, ETC.	Pounds of water heated 10° F. per hour by 1 sq. ft.
1. Clay, dung, and vegetable-fiber paste	39·6
2. Fossil meal and hair paste	10·4
3. Fossil meal and asbestus powder	26·3
4. Paper pulp, clay, and vegetable fiber	44·6
5. Paper pulp, alone	14·7
6. Stag-wood, hair, and clay paste	10
7. Asbestus fiber, wrapped tightly	17·9
8. Coal-ashes and clay paste wrapped with straw	29·9

Horse-Power of Boilers.—The committee on standard boiler trials of the American Society of Mechanical Engineers, in their report made in 1884, adopted as the unit of boiler horse-power the same that had been previously adopted by the Committee of Judges of Steam-Boilers at the Centennial Exhibition, in 1876, viz., an evaporation 30 lbs. of water per hour from a feed-water temperature of 100° F. into steam at 70 lbs. gauge pressure, "which shall be considered to be equal to 34½ units of evaporation—that is, to 34½ lbs. of water evaporated from a feed-water temperature of 212° F. into steam at the same temperature. This standard is equal to 33,305 thermal units per hour."

Code of Rules for Boiler-Tests.—In 1884 a committee of the American Society of Mechanical Engineers, consisting of Prof. R. H. Thurston and Messrs. J. C. Hoadley, Charles T. Porter, Charles E. Emery, and William Kent, presented an elaborate report on a Standard Method of Steam-Boiler Trials, in which they included the following code of rules and system of reporting the results of a trial, which have met with general acceptance among engineers in the United States:

"PRELIMINARIES TO A TEST.—I. *In preparing for* and conducting trials of steam-boilers, the specific object of the proposed trial should be clearly defined and steadily kept in view.

"II. *Measure and record the dimensions,* position, etc., of grate and heating surfaces, flues and chimneys, proportion of air space in the grate-surface, kind of draft, natural or forced.

"III. *Put the Boiler in Good Condition.*—Have heating surface clean inside and out, grate-bars and sides of furnace free from clinkers, dust and ashes removed from back connections, leaks in masonry stopped, and all obstructions to draft removed. See that the damper will open to full extent, and that it may be closed when desired. Test for leaks in masonry by firing a little smoky fuel and immediately closing damper. The smoke will then escape through the leaks.

"IV. *Have an understanding with the parties* in whose interest the test is to be made as to the character of the coal to be used. The coal must be dry, or, if wet, a sample must be dried carefully and a determination of the amount of moisture in the coal made, and the calculation of the results of the test corrected accordingly. Wherever possible, the test should be made with standard coal of a known quality. For that portion of the country east of the Alleghany Mountains good anthracite egg coal or Cumberland semi-bituminous coal may be taken as the standard for making tests. West of the Alleghany Mountains and east of the Missouri River, Pittsburg lump coal may be used.*

"V. *In all important tests* a sample of coal should be selected for chemical analysis.

"VI. *Establish the correctness of all apparatus* used in the test for weighing and measuring. These are: 1. Scales for weighing coal, ashes, and water. 2. Tanks, or water-metres for measuring water. Water-metres as a rule should only be used as a check on other measurements. For accurate work, the water should be weighed or measured in a tank. 3. Thermometers and pyrometers for taking temperatures of air, steam, feed-water, waste gases, etc. 4. Pressure-gauges, draft-gauges, etc.

* These coals are selected because they are about the only coals which contain the essentials of excellence of quality, adaptability to various kinds of furnaces, grates, boilers, and methods of firing, and wide distribution and general accessibility in the markets.

"VII. *Before beginning a test* the boiler and chimney should be thoroughly heated to their usual working temperature. If the boiler is new, it should be in continuous use at least a week before testing, so as to dry the mortar thoroughly and heat the walls.

"VIII. Before beginning a test the boiler and connections should be free from leaks, and all water connections, including blow and extra feed-pipes, should be disconnected or stopped with blank flanges, except the particular pipe through which water is to be fed to the boiler during the trial. In locations where the reliability of the power is so important that an extra feed-pipe must be kept in position, and in general when for any other reason water-pipes other than the feed-pipes can not be disconnected, such pipes may be drilled so as to leave openings in their lower sides, which should be kept open throughout the test as a means of detecting leaks, or accidental or unauthorized opening of valves. During the test the blow-off pipe should remain exposed. If an injector is used it must receive steam directly from the boiler being tested, and not from a steam-pipe, or from any other boiler. See that the steam-pipe is so arranged that water of condensation can not run back into the boiler. If the steam-pipe has such an inclination that the water of condensation from any portion of the steam-pipe system may run back into the boiler, it must be trapped so as to prevent this water getting into the boiler without being measured.

"STARTING AND STOPPING A TEST.—IX. A test should last at least ten hours of continuous running, and twenty-four hours whenever practicable. The conditions of the boiler and furnace in all respects should be, as nearly as possible, the same at the end as at the beginning of the test. The steam pressure should be the same, the water-level the same, the fire upon the grates should be the same in quantity and condition, and the walls, flues, etc., should be of the same temperature. To secure as near an approximation to exact uniformity as possible in conditions of the fire and in temperatures of the walls and flues, the following method of starting and stopping a test should be adopted:

"X. *Standard Method.*—Steam being raised to the working pressure, remove rapidly all the fire from the grate, close the damper, clean the ash-pit, and as quickly as possible start a new fire with weighed wood and coal, noting the time of starting the test and the height of the water-level while the water is in a quiescent state, just before lighting the fire. At the end of the test, remove the whole fire, clean the grates and ash-pit, and note the water-level when the water is in a quiescent state; record the time of hauling the fire as the end of the test. The water-level should be as nearly as possible the same as at the beginning of the test. If it is not the same, a correction should be made by computation, and not by operating pump after test is completed. It will generally be necessary to regulate the discharge of steam from the boiler tested by means of the stop-valve for a time while fires are being hauled at the beginning and at the end of the test, in order to keep the steam pressure in the boiler at those times up to the average during the test.

"XI. *Alternate Method.*—Instead of the standard method above described, the following may be employed where local conditions render it necessary: At the regular time for slicing and cleaning fires, have them burned rather low, as is usual before cleaning, and then thoroughly cleaned; note the amount of coal left on the grate as nearly as it can be estimated; note the pressure of steam and the height of the water-level—which should be at the medium height to be carried throughout the test—at the same time; and note this time as the time of starting the test. Fresh coal, which has been weighed, should now be fired. The ash-pits should be thoroughly cleaned at once after starting. Before the end of the test the fires should be burned low, just as before the start, and the fires cleaned in such a manner as to leave the same amount of fire, and in the same condition, on the grates as at the start. The water-level and steam pressure should be brought to the same point as at the start, and the time of the ending of the test should be noted just before fresh coal is fired.

"DURING THE TEST.—XII. *Keep the Conditions uniform.*—The boiler should be run continuously, without stopping for meal-times or for rise or fall of pressure of steam due to change of demand for steam. The draft being adjusted to the rate of evaporation or combustion desired before the test is begun, it should be retained constant during the test by means of the damper. If the boiler is not connected to the same steam-pipe with other boilers, an extra outlet for steam with valve in same should be provided, so that in case the pressure should rise to that at which the safety-valve is set it may be reduced to the desired point by opening the extra outlet without checking the fires. If the boiler is connected to a main steam-pipe with other boilers, the safety-valve on the boiler being tested should be set a few pounds higher than those of the other boilers, so that in case of a rise in pressure the other boilers may blow off, and the pressure be reduced by closing their dampers, allowing the damper of the boiler being tested to remain open, and firing as usual. All the conditions should be kept as nearly uniform as possible, such as force of draft, pressure of steam, and height of water. The time of cleaning the fires will depend upon the character of the fuel, the rapidity of combustion, and the kind of grates. When very good coal is used, and the combustion not too rapid, a ten-hour test may be run without any cleaning of the grates, other than just before the beginning and just before the end of the test. But in case the grates have to be cleaned during the test, the intervals between one cleaning and another should be uniform.

"XIII. *Keeping the Records.*—The coal should be weighed and delivered to the firemen in equal portions, each sufficient for about one hour's run, and a fresh portion should not be delivered until the previous one has all been fired. The time required to consume each portion should be noted, the time being recorded at the instant of firing the first of each new portion. It is desirable that at the same time the amount of water fed into the boiler should

be accurately noted and recorded, including the height of the water in the boiler, and the average pressure of steam and temperature of feed during the time. By thus recording the amount of water evaporated by successive portions of coal, the record of the test may be divided into several divisions, if desired, at the end of the test, to discover the degree of uniformity of combustion, evaporation, and economy at different stages of the test.

"XIV. *Priming Tests.*—In all tests in which accuracy of results is important, calorimeter tests should be made of the percentage of moisture in the steam, or of the degree of superheating. At least ten such tests should be made during the trial of the boiler, or so many as to reduce the probable average error to less than 1 per cent, and the final records of the boiler-tests corrected according to the average results of the calorimeter tests. On account of the difficulty of securing accuracy in these tests, the greatest care should be taken in the measurements of weights and temperatures. The thermometers should be accurate to within a tenth of a degree, and the scales on which the water is weighed to within one-hundredth of a pound.

"ANALYSES OF GASES.—MEASUREMENT OF AIR-SUPPLY, ETC.—XV. In tests for purposes of scientific research, in which the determination of all the variables entering into the test is desired, certain observations should be made which are in general not necessary in tests for commercial purposes. These are the measurement of the air-supply, the determination of its contained moisture, the measurement and analysis of the flue gases, the determination of the amount of heat lost by radiation, of the amount of infiltration of air through the setting, the direct determination by calorimeter experiments of the absolute heating value of the fuel, and (by condensation of all the steam made by the boiler) of the total heat imparted to the water. The analysis of the flue gases is an especially valuable method of determining the relative value of different methods of firing, or of different kinds of furnaces. In making these analyses great care should be taken to procure average samples—since the composition is apt to vary at different points of the flue—and the analyses should be intrusted only to a thoroughly competent chemist, who is provided with complete and accurate apparatus. As the determinations of the other variables mentioned above are not likely to be undertaken except by engineers of high scientific attainments, and as apparatus for making them is likely to be improved in the course of scientific research, it is not deemed advisable to include in this code any specific directions for making them."

Results of Boiler-Tests.—Mr. George Barrus, in his book on *Boiler-Tests* (1891), gives the account of tests made by him on 71 steam-boilers of different types, most of them located in factories in New England and running under ordinary conditions. From a table summarizing the results of all the tests we have made the following extract, selecting only those tests which gave an economic result of over 11·25 lbs. of water evaporated from and at 212° per lb. of combustible:

Selected Best Results from Tests of Seventy-one Different Boilers tested by Geo. S. Barrus.

KIND OF BOILER.	Ratio of water-heating to grate surface.	Ratio of steam-heating surface to grate surface.	Kind of coal.	Per cent of ash.	Coal per sq. ft. of grate per hour.	Temperature of escaping gases.	Water per lb. combustible from and at 212° F.
Horizontal return tubular	32·2 to 1	....	Cumberland.	11·1	10·1	435	11·52
" " "	33·5 to 1	4·1 to 1	Anth. broken.	12·5	8·7	340	11·63
" " " *....	42 to 1	....	Cumberland.	6·6	14	381	11·37
" " " †....	37 to 1	....	"	6·6	9·1	387	11·78
" " "	37 to 1	....	Pea and dust, 2 parts, Cumb., 1.	11·4	10·7	387	11·60
" " "	41·6 to 1	....	Cumberland.	6·6	7	431	12·07
" " "	40 to 1	....	"	6·5	11·1	408	11·98
" " " ‡....	57·9 to 1	....	Anth. broken.	10·3	11·9	321	11·33
" " "	57·9 to 1	....	Cumberland.	8·3	12·1	397	11·99
" " "	57·9 to 1	....	Anth. scr'gs, 6 parts, Cumb., 4.	8·7	12·2	367	11·30
" " "	53·1 to 1	....	Cumberland.	7·5	13·6	413	12·47
" " " §....	61 to 1	....	"	7	7·96	322	11·81
" " " §....	65 to 1	....	"	6·7	10·97	389	12·42
" " " §....	62·1 to 1	....	"	9·7	9·3	375	12·03
" " " §....	58 to 1	4 to 1	"	....	12·5	....	11·78
Vertical tubular................	35·1 to 1	4 to 1	Clearfield.	9·3	10·3	423	12·29
Vertical fire-box	44·5 to 1	15·7 to 1	Cumberland.	7·7	13·1	427	12·29
Water-tube.....................	40 to 1	....	Anthracite pea.	17·4	12·2	353	11·44
" "	62·5 to 1	....	Pea and dust, 1 part, Powelton, 3 parts.	9	16·7	402	13·01

* With double passage of gases. † With water-leg front. ‡ Detached furnace. § Double deck.

This table shows the best results which may be expected in ordinary practice. That ordinary or average practice falls much below the best is shown by the fact that out of 71 boilers tested only 16 gave an evaporation equal or greater than 11·25 lbs., and of these only 6 gave over 12 lbs., 15 between 9 and 10 lbs., and 7 below 9 lbs. The poorest results were given by plain cylinder boiler having a ratio of water-heating to grate surface of only 10·9 to 1, and a temperature of escaping gases of over 600°. The best results were reached with several forms of boiler, including the ordinary return tubular boiler, by the vertical tubular boiler, and by the water-tube boiler. The following table shows the principal results obtained from tests of 16 horizontal tubular boilers:

Results of Tests of Horizontal Tubular Boilers with Anthracite Coal.

	Ratio of heating to grate surface.	Per cent of ash.	Coal per hour per sq. ft grate.	Temperature of escaping gas.	Water per lb. combustible from and at 212° F.
			Lbs.	Deg. F.	
Average of 16 boilers	44·7 to 1	12·2	11	387·9	10·76
Highest economy	35·6 to 1	13·4	6·7	321	11·37
Lowest economy	26·5 to 1	10·1	12·9	455	9·75

In general, the highest results are produced where the temperature of the escaping gases is the least. An examination of this question is made by Mr. Barrus, by selecting those tests made by him, six in number, in which the temperature exceeds the average, that is 375°, and comparing with five tests in which the temperature is less than 375°. The boilers are all of the common horizontal tubular type, and all use anthracite coal of either egg or broken size. The average flue temperature in the two series are 444° and 343°, respectively, and the difference is 101°. The average evaporations are 10·40 lbs. and 11·02 lbs., respectively, and the lowest result corresponds to the case of the highest flue temperature. In these tests it appears, therefore, that a reduction of 101° in the temperature of the waste gases secured an increase in the evaporation of 6 per cent. This result corresponds quite closely to the effect of lowering the temperature of the gases by means of a flue-heater in another test, where a reduction of 107° was attended by an increase of 7 per cent in the evaporation per lb. of coal. A similar comparison was made on ten horizontal tubular boilers using Cumberland coal. The average flue temperature of the ten boilers was 415°. Four of them had temperatures exceeding 415°, their average temperature being 450°, and average evaporation 11·34 lbs. The other six had temperatures below 415°, averaging 383°, and their average evaporation was 11·75 lbs. With 67° less temperature of the escaping gases, the evaporation is higher by about 4 per cent. The difference here is less marked than in the anthracite tests, both in range of temperature and in economy, but it is in the same direction; that is, the highest evaporation is produced where the waste at the flue is the least. The wasteful effect of a high flue temperature is exhibited by other boilers than those of the horizontal tubular class. This source of waste was shown to be the main cause of the low economy produced in those vertical boilers which are deficient in heating surface. As to the proper ratio of heating to grate surface, Mr. Barrus concludes that a ratio of 36 to 1 provides a sufficient quantity of heating surface to secure the full efficiency of anthracite coal where the rate of combustion is not more than 12 lbs. per sq. ft. of grate per hour, and a ratio of 45 to 50 to 1 for bituminous coal. As to tube area he concludes that the highest efficiency with anthracite coal is obtained when the tube opening is from one ninth to one tenth of the grate surface; but a large tube opening is required with bituminous coal, the best results being obtained where the tube opening was from one fourth to one seventh of the grate area. The general conclusion drawn from all these comparisons is that the economy with which different types of boilers operate depends much upon their proportions and the conditions under which they work, than upon their type; and, moreover, that when these proportions are suitably carried out, and when the conditions are favorable, the various types of boilers give substantially the same result.

Prevention of Corrosion of Marine Boilers.—Mr. H. J. Bakewell, in *Proc. Inst. Mech. Eng.*, August, 1884, p. 352, writes, concerning the British Admiralty practice on the treatment of marine boilers, as follows:

"The investigations of the Committee on Boilers served to show that the internal corrosion of boilers is greatly due to the combined action of air and sea-water when under steam, and when not under steam to the combined action of air and moisture, upon the unprotected surfaces of the metal. There are other deleterious influences at work, such as the corrosive action of fatty acids, the galvanic action of copper and brass, and the inequalities of temperature; these latter, however, are considered to be of minor importance.

"Of the several methods recommended for protecting the internal surfaces of the boilers, the three found most effectual are: firstly, the formation of a thin layer of hard scale deposited by working the boiler with sea-water; secondly, the coating of the surfaces with a thin wash of Portland cement, particularly wherever there are any signs of decay; thirdly, the use of zinc slabs suspended in the water and steam spaces. As to general treatment for the preservation of boilers in store or when laid up in the reserve, either of the two following methods is adopted, as may be found most suitable in particular cases: Firstly, the boilers are dried as much as possible by airing stoves, after which 2 to 3 cwt. of quicklime, according to the size of the boiler, is placed on suitable trays at the bottom of the boiler and on the tubes. The boiler is then closed and made as air-tight as possible. Periodical inspection is made every six months, when if the lime be found slacked it is renewed. Secondly, the other method is to run the boilers up with sea or fresh water, having soda added to it; if ordinary crystal soda be used, the proportion is 1 lb. of soda to every 100 or 120 lbs. of water. The sufficiency of the saturation can be tested by introducing a piece of clean new iron, and leaving it in the boiler for ten or twelve hours; if it shows signs of rusting, more soda should be added. It is essential that the boilers be entirely filled, to the complete exclusion of air. The working density of the water used in boilers is from 2½ to 4 times the saltness of sea-water; a high density has been found beneficial in point of cleanliness. It is considered advantageous to retain the water in boilers without change as long as possible, whether the fires are alight or not, and to remove it only when dirty, or when necessary for cleaning and examination, the boilers being filled up quite full when not required for steaming.

"With the view of ascertaining the condition of the water in boilers in respect of its acidity, neutrality, or alkalinity, it is the practice to test the water in each boiler with litmus-paper once in 24 hours when the fires are alight, and once in 7 days when they are not. Should the water be found in an acid condition, a small quantity of carbonate of soda is introduced with the feed-water to neutralize the acidity. The state of the water at each test is recorded.

"Great care is taken to prevent sudden changes of temperature in boilers. Directions are given that steam shall not be raised rapidly, and that care shall be taken to avoid a rush of cold air through the tubes by too suddenly opening the smoke-box doors. The practice of emptying boilers by blowing out is also prohibited, except in cases of extreme urgency. As a rule, the water is allowed to remain until it becomes cool before the boilers are emptied. Mineral oil has for many years been exclusively used for internal lubrication, with the view of avoiding the effects of fatty acid, as this oil does not readily decompose, and possesses no acid properties.

"Of all the preservative methods adopted in her Majesty's service the use of zinc properly distributed and fixed has been found the most effectual in saving the iron and steel surfaces from corrosion; and also in neutralizing by its own deterioration the hurtful influences met with in water as ordinarily supplied to boilers. The zinc slabs now used in the navy boilers are 12 in. long, 6 in. wide, and ½ in. thick, this size being found convenient for general application. The amount of zinc used in new boilers at present is one slab of the above size for every 20 indicated horse-power, or about 1 sq. ft. of zinc surface to 2 sq. ft. of grate surface. Consideration is now being given to the subject to see if this proportion of zinc can be reduced without detriment. Rolled zinc is found the most suitable for the purpose, and is now always issued for use. To make the zinc properly efficient as a protector, special care must be taken to insure perfect metallic contact between the slabs and the stays or plates to which they are attached. The slabs should be placed in such positions that all the surfaces in the boiler shall be protected. Each slab should be periodically examined to see that its connection remains perfect, and to renew any that may have decayed; this examination is usually made at intervals not exceeding three months. Under ordinary circumstances of working, these zinc slabs may be expected to last in fit condition from 60 to 90 days, immersed in hot sea-water; but in new boilers they at first decay more rapidly. The slabs are generally secured by means of iron straps, 2 in. wide and ⅜ in. thick, and long enough to reach the nearest stay, to which the strap is firmly attached by screw-bolts. Great attention is paid to the cleanliness of boilers, and special instructions are in force for their periodical and thorough examination. The usual interval is three months, but other examinations are made within this time as opportunity offers, and according to the circumstances of working, at the discretion of the engineer in charge. With regard to the results of the present practice founded on the recommendations of the Boiler Committees, it may be said in general terms that, with proper observance of the regulations laid down for the guidance of engineer officers, corrosion in the boilers of the Royal Navy could hardly take place. At the present time reports of serious corrosion in boilers are of very rare occurrence."

Determination of Moisture in Steam (*see also* CALORIMETER).—In measuring the performance of a boiler, the essential determination is the quantity of heat utilized by the generation of steam. If the steam generated at say 90 lbs. pressure is dry steam, then for each pound of feed-water the boiler is to be credited with utilizing 120 heat-units, due to the temperature of the steam if the feed-water is at 200° F., and 808 heat-units due to its latent heat, or a total of 928 heat-units. If, however, 10 per cent of the steam is liquid water mechanically mixed with 90 per cent of dry steam, then for each pound of feed-water the boiler is to be credited with 1.10×120 heat-units, due to temperature, and 0.90×808 heat-units, due to latent heat, or a total of 859 heat-units, which is 92 per cent of the dry steam total. Unless, therefore, allowance for the presence of moisture is made, the efficiency of a boiler at ordinary steam pressures is made too great at the rate of $\frac{8}{10}$ per cent for each 1 per cent of water in the steam. Again, if steam at 90 lbs. pressure is superheated 10° F., so that its temperature is 330° F., then for each pound of feed-water at 200° F. we must credit the boiler with the heat due to dry steam plus $0.48 \times 10° = 4.8$ heat-units, so that failure to allow for superheating makes the efficiency of a boiler, at ordinary pressures, too low by about 0·05 per cent for each degree F. of superheating. It is customary among experts to make these allowances in reporting the performances of boilers, and hence arises the necessity of determining to what extent the steam generated by a given boiler differs from exactly dry steam. If the steam is superheated, the simple observance of its temperature by a proper thermometer affords the desired data. If, however, the steam is shown by a thermometer to be at exactly the temperature due to saturation, it may contain any amount of water in suspension, and the determination of the amount of the latter can in general only be accurately known by a measurement of either the latent heat or density of a known weight of the mixture. The determination of the density is an operation too delicate to have been yet attempted with portable apparatus. The determination of latent heat involves simply the condensation or mixture of a known weight of steam in or with a known weight of some other substance of known specific heat, and the operations to be performed are such as can be carried out with apparatus of a conveniently portable nature.

Prof. James E. Denton, of the Stevens Institute of Technology, has made an investigation into the appearance of jets of steam containing various degrees of moisture, which lead to the following conclusions (*Trans. A. S. M. E.*, vol. x, p. 349):

I. It appears that jets of steam show unmistakable change of appearance to the eye when

steam varies less than 1 per cent from the condition of saturation either in the direction of wetness or superheating.

II. If a jet of steam flow from a boiler into the atmosphere under circumstances such that very little loss of heat occurs through radiation, etc., and the jet be transparent close to the orifice, or be even a grayish-white color, the steam may be assumed to be so nearly dry that no portable condensing calorimeter will be capable of measuring the amount of water in steam. If the jet be strongly white, the amount of water may be roughly judged up to about 2 per cent, but beyond this a calorimeter only can determine the exact amount of moisture.

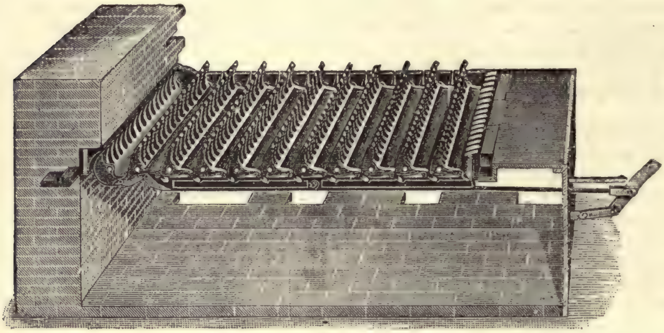


FIG. 18.—The McClave grate.

III. A common brass pet cock may be used as an orifice, but it should, if possible, be set into the steam-drum of the boiler, and never be placed farther away from the latter than 4 ft., and then only when the intermediate reservoir or pipe is well covered.

The McClave Grate and Furnace-Blower.—Fig. 18 shows a new form of shaking grate recently devised for burning anthracite buckwheat and culm, together with a steam-blower used under the grate for the purpose of creating a forced blast without a great excess of steam. This grate operates on the pocket principle—i. e., when the grate-bars are thrown wide open, a series of pockets are formed by them to receive the clinkers and ashes, but which can not pass through into the ash-pit until the bars are thrown back into their normal position, thus mowing a certain quantity of clinkers and ashes from the under side of the fire instantly and uniformly at each cut. The Argand steam-blower, shown in Fig. 19, is used in connection with the McClave grate to furnish a forced draft. It furnishes a large volume of air with a small amount of steam; and the air and steam are thoroughly mixed in the shell or case of the blower before the blast is delivered into the ash-pit. It is now generally conceded that a blast furnished by under-grate blowers is better adapted to burn small fuels, such as buckwheat, birdseye, culm, slack, etc., than either a strong natural draft, or yet a draft produced by a jet or jets in the stack. The idea of a combined air and steam blast has gradually grown into favor on account of the effect of the steam on the fire. It is a well-established fact, however, that while a small quantity of steam is a valuable constituent in blast, yet an excess of steam defeats the very purpose for which it was intended, by over-taxing the decomposing power of the fire with too large a quantity of steam, which passes through the fire simply as steam, thereby losing the value of the oxygen it contains, nearly the entire product of the fire being in such case carbonic oxide, with no available oxygen present to combine with it. The mechanical effect of the steam is that it keeps the clinkers soft and porous, so that the blast will readily pass up through the entire bed of fuel uniformly, instead of being forced to pass between solid clinkers wherever it can find an opening, thus producing what is generally termed forge flames under the boiler, as is usually the case with a fan-blast; for with an all-air blast the clinkers generally form into compact slabs, through which the air can not pass. Therefore, while heat is absorbed in the decomposition of steam, yet the heat thus absorbed is more than compensated for by the beneficial nature of the general result thus obtained. See also Engines, Steam Fire, Locomotive, Ice-Making Machines, and Drilling Machines, Metal.

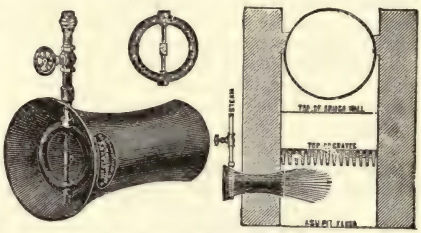


FIG. 19.—McClave Argand blower.

BOILER-TUBE CLEANER. *Baldwin's Boiler-Tube Cleaner* is shown in Fig. 1. This cleaner differs from the ordinary tube-cleaner in that the deposits, instead of being blown out of the tubes into the back connection, are drawn by a partial vacuum from the rear end to the front, and discharged into the chimney, or other convenient place, without admitting steam into the tubes. This is accomplished by an apparatus working upon the injector principle. Steam is admitted through the small apertures shown. A strong suction is produced in the direction of the arrows. The larger end is held into the boiler-tube, a packing securing tight

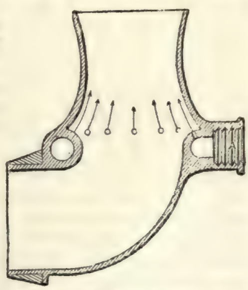


FIG. 1.—Tube cleaner.

connection, and the deposit from the tube is drawn through the unobstructed passage and discharged from the mouth of the apparatus with a velocity sufficient to clean the tube to which it is applied, discharging the contents out of the chimney-top.

BOLT-CUTTER. *The Merriman Bolt-Cutter, or Threading Machine,* is shown in Figs. 1 and 2. The vital portion of the machine is the head or chuck, which consists of four

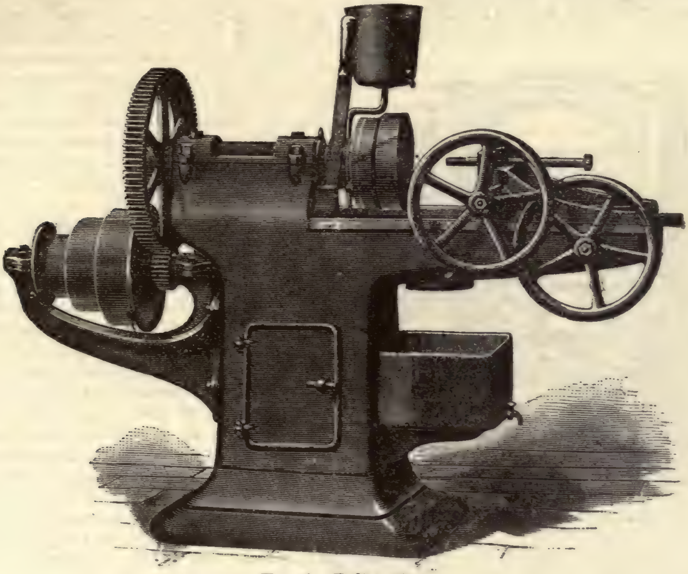


FIG. 1.—Bolt-cutter.

principal parts, as shown in Fig. 2. 1. The die-box, which is made of steel and contains the four die-slots, in which the dies are accurately fitted and firmly held. 2. The ring, which surrounds the die-box and receives the thrust or bearing of the dies when in operation. 3. The flange, which slides longitudinally upon the spindle, or shaft, in the rear of the ring, to which it is attached by two screws that pass through the two long slots into holes in the rear of the ring (not shown in the cut). 4. The cap, which is secured to the die-box by four screws that pass through the four holes in its face. In the rear of the die-slots are the four small levers, or "dogs," that serve to lift the dies from the bolt when the thread has been cut. As the flange and ring are fastened together by the slot-screws, when these parts are drawn back by means of the lever (see cut of the machine), the rear ends of the "dogs" are depressed, and the front ends, engaging under the projection or "nib" of the dies, lift the dies and release the bolt. When the ring is brought forward it strikes the inclines on the dies, which are then forced down in their slots and are again ready for service. Inside the ring are three

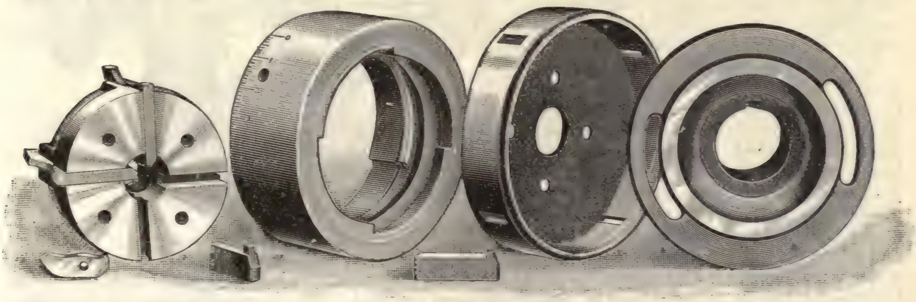


FIG. 2.—Bolt-cutting head.

sets, or series, of hardened steel eccentrics, on the outer one of which the dies have their thrust, or bearing, when in working position. By loosening the two slot-screws the ring may be rotated independently upon the die-box, a distance governed by the length of the die-slots, thus causing the eccentrics to operate upon the dies for their adjustment to such a degree as may be desired. By this means the dies may be made to cut the bolt to the size needful to make a tight or loose fit in the nut. The Merriman die is made of a plain piece of steel, milled or planed so as to leave a short "nib" or projection, under which the "dog" engages and lifts the die from its work. These dies can be recut several times for their original size of bolt; and after that capability has been exhausted, they can be recut for use on larger sizes of bolts

that do not require so long dies. In operating the machine the thread is cut with four dies, which are fixed in the head upon a hollow shaft, and revolve around the bolt, which is held stationary in a vise operated by a right and left screw on the shaft of the small hand-wheel. The dies cut the thread by passing over the bolt but once. When the thread has been cut as far as desired, the dies are opened by moving the lever, and the bolt is withdrawn, while the machine still continues in motion.

BOOK-BINDING MACHINES. The art of book-binding has witnessed few changes so far as theory is concerned during the past decade, and consequently the efforts of inventors in this trade have been mainly directed toward perfecting and improving the machinery and appliances used in the work, the changes being notably in cutters, edge-trimmers, folders, presses, wire and thread sewing machines, rounders and backers, and inking attachments for embossing-presses.

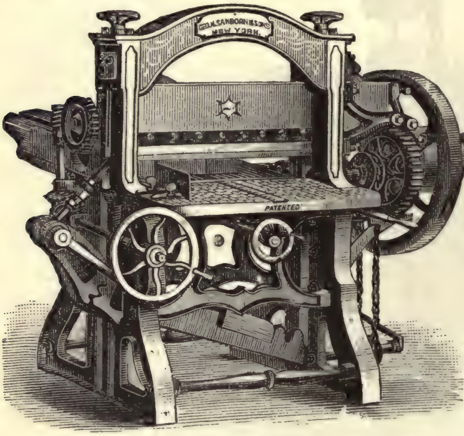


Fig. 1.—Star paper-cutter.

Cutters.—The so-called "Star" machine is represented in Fig. 1. It is so constructed that the operator can stop the knife instantaneously at any point, when it will run back automatically to the starting-point. The cut is made and the knife returned at four turns of the fly-wheel, and the gearing is such that only a slight effort is necessary to work it by hand. By the use of the long-toothed end-lever, working in a curved rack, the power is largely increased, and this suits the cutter for exceptionally heavy work, such as the continuous cutting of all kinds of mill and pulp board, glazed or enameled cardboard and paper, and other tough materials. In another type of paper-cutter, known as the "Criterion," the knife is operated by a center crank-movement located below the cutting-table. so that the strain of cutting is applied where the frame is the strongest. The clamping device combines a hand-screw clamp with an automatic power-clamp, so that in operating the same the pressure can be applied to the hand-wheel to any degree, after which the power-clamp will duplicate the given pressure exactly.

In the "Inland" cutter a power screw-clamp, with a power knife-mechanism, make a combination of an automatic self-clamping device and an independent power-clamp in one machine. The clamp is set in motion, and its up-and-down movement to any required pressure is controlled by a treadle. The knife is started by a hand-lever, which enables the operator to stop or reverse instantly at any point. Only one screw is required to be adjusted in regulating the depth of the knife.

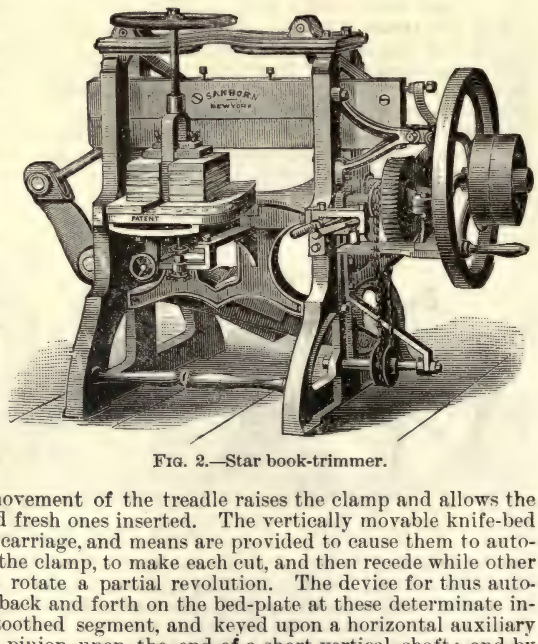


Fig. 2.—Star book-trimmer.

Book-Trimmers.—The main features of a novel form of trimmer are the clamp operated up and down by means of an oscillating treadle, allowing the operator to use both hands to handle the bunches. After the clamp is applied, the machine is started by means of a hand-lever, and then operates to make four consecutive cuts and turns of the table, after which it stops automatically, and a reverse movement of the treadle raises the clamp and allows the trimmed bunches to be removed and fresh ones inserted. The vertically movable knife-bed and knife are mounted in a traveling carriage, and means are provided to cause them to automatically approach the form-plate of the clamp, to make each cut, and then recede while other automatic means cause the table to rotate a partial revolution. The device for thus automatically moving the knife-carriage back and forth on the bed-plate at these determinate intervals consist of a disk having a toothed segment, and keyed upon a horizontal auxiliary shaft, said segment meshing with a pinion upon the end of a short vertical shaft; and by means of a loose pinion at the upper end of this vertical shaft working in a rack running in the bed-plate, the knife-frame is operated at the proper time. The shearing action of the knife is produced through a lever having a roller at its upper end, and bearing upon the edge of the knife-bed; a roller on the lower end of this lever bears against a cam upon the shaft,

and, the lever being pivoted centrally in the framing, oscillates at intervals and effects the movement of the knife.

The "*Star Book-Trimmer*," manufactured by George H. Sanborn & Sons, of New York, is shown in Fig. 2. The rotation of the table is effected by hand, and the clamp is operated by the large hand-wheel shown. The hand-wheel in front regulates the movable bed for large and small books. After the knife has come down, the turn-table unlocks itself, and again automatically locks before the next cut is made, thus doing away with the old-fashioned lock which required the operator to push in a key in front before making a cut. This improvement saves time and hard work, and in connection with the rapidly moving knife makes this type of machine one of the fastest trimmers in the market. Reverse motion of the gearing is stopped by an improved friction-brake. The knife-bar slides diagonally in heavy frames, and a true and smooth cut is insured at each descent of the knife. The small hand-wheels under the front of the bed are for the purpose of instantly adjusting the work whenever there is any tendency of heavy work crowding the knife: this keeps the latter from cutting "in" or "out" from a true plane, and is a valuable feature of the machine. The rise of the knife is adjustable for the thinnest or thickest piles.

Book-Folding Machines.—The machine illustrated by Fig. 3 embodies the latest improvements made by the Chambers Brothers Co., of Philadelphia. It is what may be termed a "side-registering drop-roller machine." Instead of feeding the sheets to register-pins, as in the older style of book-folding machines, the sheet is fed to a side guide and to a drop-roller. The drop-roller, running at a high velocity, carries the sheet into the folding-machine very quickly, and enables the speed of a hand-fed machine to be increased from about 1,000 sheets per hour to from 2,000 to 2,400 per hour. In feeding, the same guide and nipper-edges are used as in the press-feeder when printing the sheet, and after the sheet enters the folding-machine, an automatic device—working to the same position on the margin as was used when feeding the sheet on the printing-press—pulls the sheet into exact position, so that the intended line of the fold is immediately under the first fold-blade. Thus, if the margins of the printed sheets are uniform—so that when the device is once adjusted to suit any particular distance it is right for all the sheets—then the register obtained in folding will be equal to that obtained in printing. This side guiding, as it is termed, is accomplished automatically within the folding-machine, so that the register is not dependent upon the accuracy with which the operator may feed the sheet. He may fail to place the sheet within ⅜ of an in. of the intended position, and still the machine will automatically bring it to the required position before the fold is made. This is the main feature that is new in this machine. The machine is so designed that an automatic feeding attachment, known as the Sedgwick feeder, can be connected with the folding-machine, and the combined mechanism

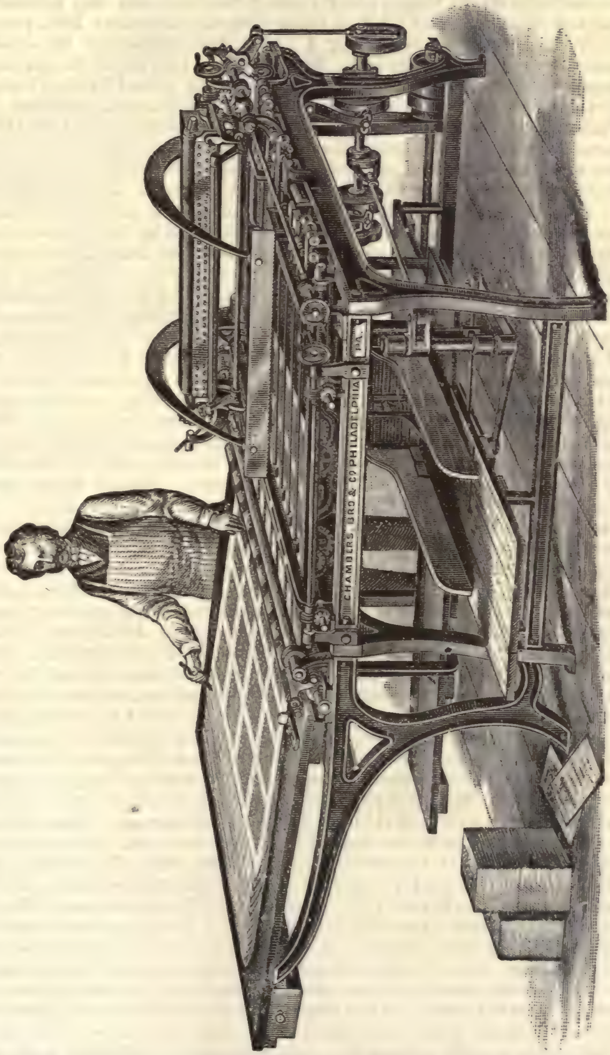


FIG. 3.—Chambers's book-folding machine.

work for two or three hours at a time without any attention other than to take away the folded sheets. Such a combination is in successful use. It is built either as a plain folder or folder and paster, with or without covering attachment. It is intended for working "whole sheets" as printed on the press, so that the same guide and nipper-edge may be used on the folder as were used in feeding on the press. The sheet is thus folded accurately by the edge, and the register is as good as that obtained in printing. It has a capacity of 2.000 sheets per hour.

Point-fed Registering Book-Folders have not been materially altered during several years, and any advance made in this type of machine has been confined to minor improvements in construction and detail to suit special demands of publishers.

Combination Folding, Pasting, and Covering Machines are coming more largely into use for periodical and pamphlet work. These machines, as their name indicates, perform all the operations of folding, pasting, and covering a pamphlet of 12, 16, 24, 32, or 36 pages, and produce at each revolution a complete pamphlet, covered, ready to trim. A paster and coverer will do all that a plain folding-machine will do: folding to register without either pasting or covering; fold and paste without covering; fold, paste, and cover with different color or quality of paper; or 4 additional pages may be added to a periodical when an increase of pages is desired. Machines are also built for putting on covers of either 4 or 8 pages—whereby an advertising sheet may be added to a periodical—or the number of pages increased by 4 or 8, as desired, or by an independant sheet of 8 pages folded and pasted. These machines, when covering, require two operators, one for the main sheet and one for the cover. There is also in course of construction a new machine that will not only fold and cover the main sheet with 4 or 8 pages, but will also work an "insert" of either 4 or 8 pages, thus enabling the publisher to issue a paper or magazine of 32, 36, 40, 44, or 48 pages at will.

Pamphlet-Binding Machine.—In binding pamphlets with paper, or other soft covers, a beneficial forward step in the art has been made by the introduction of the Clague & Randall pamphlet-binding machine. This is made up of automatic devices for laying the paste upon the covers, for feeding the stitched books forward to the covers, for folding the pasted covers in proper position upon the stitched bodies, and for pressing and finishing the bound pamphlets. In the rear of the machine there is a vertically and intermittently moving shelf or platform, upon which the stitched pamphlets are piled backs inward, and at the upper rear part of the machine proper is situated a reciprocating feeding-rake which "stabs" or rakes the top pamphlet from the "bank" and deposits it upon one or more carrying belts, by which it is taken forward. The rear movement of the feeding-rake causes the platform to rise, leaving the next pamphlet in position to be caught at the proper time. When the pamphlet has been carried forward by the belts to their forward drum, it drops with its back downward upon a horizontal stop-plate upon which it rests momentarily till the stop is withdrawn to the rear by the action of a cam and connecting levers. Then it drops between feeding-rollers, being assisted by vertically moving belts having a guide-roller, against which it is forced by a friction-roller actuated by levers operated from the cam. The friction-roller has a resilient axis, so as to accommodate differing thicknesses of pamphlet. The pamphlet has now closely approached the point where the cover is to be applied. The cover is fed into the machine from a table placed at right angles to the pamphlet shelf—i. e., at one side of the machine, and is automatically carried to its position under the entering pamphlet by means of revolving belts. Previously, however, to reaching its destination it is stopped by a gauge while paste is applied in a line across the center of the cover-blank by a paster fed from a paste-trough. To prevent the paste from drying before meeting the pamphlet, the under side of the central part of the cover-blank is dampened by a roller revolving in water contained in a small trough. As the pamphlet passes between and is forced along by the feeding-rollers, it meets the cover lying upon the belts with its pasted side uppermost, which is thus, by the advance of the pamphlet, folded over the latter (the paste line meeting the back of the pamphlet), and both are pushed between and grasped by a second pair of compression rolls which complete the folding and press the two firmly together. One of each pair of rollers has yielding bearings so as to provide for different thicknesses of pamphlets. They are driven through gears from the main driving-shaft of the machine. Between the above-mentioned sets of rollers and parallel therewith, are two extra sets of smaller rollers, one pair to guide the pamphlet and insure its squarely meeting the pasted cover, and the other set to draw the cover tight before it meets the second pair of compressors. From the latter the pamphlet falls upon a chute, down which it slides to a finishing press consisting of two jaws, one movable; a sliding stop supports the book until the jaws are closed by the action of a cam and levers. After this press has closed and the stop retired, a backing roller of yielding material and oscillating upon a center sweeps around and squares up the back (which otherwise would remain rounded, owing to the drawing action of the rollers), pressing the cover into close contact at the back, while the press does the same at the sides of the pamphlet. The backing roller automatically retires, the press opens and the finished pamphlet drops upon a fixed platform, when a follower is pushed forward (toward the rear of the machine), pressing the pamphlet against a rest attached to an extensible apron. When the number of books exceeds the length of the platform upon which they are meanwhile drying, an attendant removes them in a finished state.

Embossing-Presses.—Inventors have given considerable attention to embossing-presses, their objective point being to so construct the press that no amount of wear will render the impression unequal or irregular. The principle of the sector has been found well adapted to obtain this desired result, as to give ample time to "dwell" upon the impression. A late type of embossing-press is fitted with steam-head and improved stamp-clamps. The bed is

adjustable. The impression is given by the use of a plain crank and sectors, a mechanical device by which almost any amount of pressure can be obtained. Any varying motion, with rests or dwells at either end of the stroke, may be made, thus enabling one crank to produce all the desirable movements.

Chambers'-Automatic Board-Cutter (Fig. 4).—This machine makes 50 cuts per minute, and the boards may vary in size from 3 in. × 5 in. to 9¼ × 12½ in., one cut being made in each revolution. It has an iron feed-table and an automatic feeding device working in slots through the table. By this device the strips are fed positively and squarely, thus preventing cutting out of

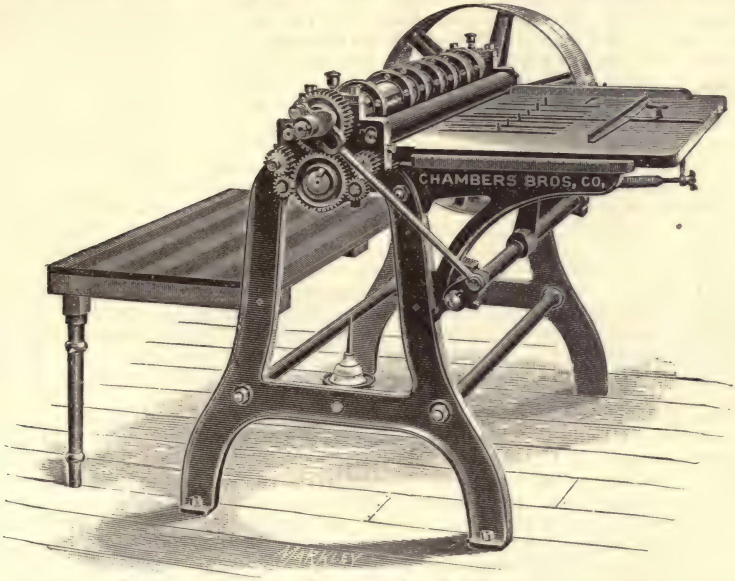


FIG. 4.—Chambers's board-cutter.

square. When feeding whole boards or strips by hand, the feeding fingers are dropped below the table, out of the way. The table is also furnished with adjustable side guides and hand-feeding device. The feeding-table is stationary, and forms a part of the framing of the machine. A delivery-table, upon which the cut boards pile automatically, is attached, thus making the machine complete within itself.

Book-Sewing Machines.—The "Brehmer" wire-sewing machine sews together the sections of books on tapes or crash. It is used for both printed and blank work, and the manufacturers claim that it makes a strong book, which can be opened flat more easily than books sewed by hand. A machine which has proved to be of great advantage to binders is the "Smyth" thread-sewing machine, described in a former volume of this work. As the machine is now built, the sheets are placed one at a time on radial arms which project from a vertical rod. These arms rotate, rise and adjust the signature, so as to bring it in its proper position under the needles. One needle of each pair enters the back of the sheet, and the eye carrying the thread comes up through the fold, just touching the "loopers." The loopers are then tilted and thrown back, leaving loops around the point of the needles. By a simple device the threads are drawn tight; the loopers then move forward, taking the thread from the needles on the inside, near the eye, and as the needles withdraw, they interlock their thread through the loops of the stitches of the previous sheet. Long horizontal wires or "needles" are laid directly in the path of the saw-cut, and the stitches made over them. The sewed work is pushed back automatically along these needles, which are threaded with the cords or bands on which the books are sewed. The sewed volumes are then separated by cutting certain threads, and drawn over the cords. These cords (or "bands") are cut off at lengths to suit the requirements of each book. The first and last two sheets of each book are pasted together to facilitate cutting the books apart and to prevent the cut thread, at these points, from being drawn into the center of the sheet by the subsequent process of binding. The pasting is done by a simple device consisting of two small rolls—one of which carries paste on its rim, while the other holds sheets in place. It is done before the sheet is sewed. By thus pasting these two signatures, no extra care is necessary in the further handling of the books to preserve the stitches in first and last sheets, and the same are made more secure by reason of the pasting. One, two, three, or four "band" work can be done as may be required, irrespective of thickness. Each pair of stitches being entirely independent of all the others, a book of blank pages may be cut into as many smaller volumes as there are pairs. Thus, on a machine with three pairs of needles, diaries or other small blank-books may be sewed three at a time, and afterward cut apart. Some of its advantages are stated as follows: Unlike hand-sewing, each and every sheet is sewed to the preceding one. The stitches in

center of the sheet are the same as at either end—practically "kettle-stitches"; these stitches are shorter (about 1 in.) and more numerous. Each sheet receives the same number of stitches, and forms practically what is termed "all along" or "one sheet on" sewing; it is stronger even than that style of sewing, because each stitch is made independent of the bands. Every three sheets form a "lock-stitch," a distinctive feature of strength in itself. Every stitch is independent. The loss of one stitch in no way affects the others. In rounding and backing the book, no strain is brought to bear on any one stitch or thread, as is the case with "kettle"-stitches by hand-work, as every stitch, it must be remembered, is practically a "kettle"-stitch; but each sheet is brought closer together, the center tightening same as at each end, and all bearing the strain alike. The process is likened to the lacing of a shoe. This gives the book a firmness and strength in the center not found in ordinary sewing. The thread enters the book with all its original strength; it is not "frayed" away by continual use, and has in comparison no knots. The stitches alternate in every sheet, so that no unusual amount of "swell" results. As will be understood, the sheets are placed on the rotary arms. These are four in number, which carry the signature from the operator to the needles. One is always presented to the operator, and rests while the preceding arm holds its sheet for operation of needles. Working from left to right, the sheet is always in sight of the operator, and always under control. The machine runs easily at a speed of 45 sheets per minute. The latest improvement made upon this machine is the substitution of automatically operated knives for making the incisions in the fold, for the punches used in connection with the first machines. These knives lie normally within the radial arms, which are made hollow. As any arm is brought into line with the row of needles, and has risen to a point just short of contact therewith, the end of a spring-bar, to which the knives are connected inside the radial arm, comes in contact with a moving device at the side of the machine, which presses such spring-bar inward, and thus causes the connected knives to protrude from the upper edge of the arm through properly spaced apertures. The knives thus make the necessary incisions in the sheets, through which the needles work when the knives are automatically withdrawn.

Stabbing-Machines.—In a new form of power stabbing-machine the main feature is that the awls revolve. While going into and coming out of the work, they turn, thus operating much easier, especially in thick books and making a smoother and smaller hole than when the stabbing is done in the usual way. A pinion on the driving-shaft meshes with a gear upon the eccentric shaft, and the eccentric, through a vertical yoke and cross-bar connected to vertical slide rods passing through the table, and terminating in the awl cross-head, causes the latter to move up and down at proper intervals for piercing the work. The cross-head travels upon stationary guide-bars which have their own fixed head, containing threaded boxes which receive the correspondingly threaded upper ends of the awls, in this way imparting rotary motion in reversed directions to the awls as their cross-head is moved up and down by the eccentric. In forming backs for blank-books, and for small job-work, a simple machine is employed which has two pairs of rolls, of different sizes, journaled in a plain upright frame which is fixed to a table. One of each pair of rolls has self-adjusting spring bearings, and each pair is geared together. A key-crank turns either pair of rolls at the will of the operator, according to the size of back he is making. The rolls are heated by gas, by gas-pipes placed back of the rolls, and both pairs can be heated at once or separately. Each roll has an apron attached to it. The book back is formed by wetting it on one side with a sponge, and feeding it in dry side next to the roll. The roll is stopped for a moment just before the back passes out, so as to give it a chance to take shape and harden; then it is released. Bands are formed in the same way by setting them in a band board and feeding them to the roll. Among the advantages are the facilities for forming different sizes and thicknesses of backs in the same machine—and a dozen or more bands at the same time as one—while producing harder and better work than can be done by hand, and saving time and labor.

Boring-Machine: see Boring Machines, Metal; Boring Machines, Wood; Lathe Tools, Milling Machines, Mortising Machines, and Wheel-Making Machines.

BORING-MACHINES, METAL. These are classified under: I. Horizontal Boring-Machines; II. Vertical Boring-Machines.

I. Horizontal Boring-Machines.—*The Niles Horizontal Boring, Drilling, and Milling Machine* is shown in Fig. 1. The machine consists of a heavy column 10 ft. 6 in. high, mounted on a bed-plate of any length to suit requirements. The column is 31 in. wide on the face, and is fitted with a heavy saddle, 40 in. square, carrying the spindle. The saddle has a vertical traverse on the column of 6 ft., and is raised and lowered by a heavy screw. It is balanced by a counter-weight hung in the column. The boring and milling spindle is of hammered steel $5\frac{1}{2}$ in. in diameter. It slides in a heavy revolving sleeve, and has a traverse of 4 ft. It revolves in either direction, right or left hand, reversing by lever conveniently located, and has 8 power-feeds, ranging from $\frac{1}{20}$ to $\frac{1}{4}$ in. per revolution of spindle. It is also provided with hand-feed and quick return. The milling-feeds are six in number, ranging from $\frac{1}{12}$ to $\frac{9}{16}$ in. per revolution of spindle. These feeds are applied only to the column and saddle, and are by power only. Any of these feeds for the quick motion may be utilized to set a drill, boring-bar, or milling-cutter to work anywhere on the surface which the machine will reach. At one end of the bed-plate is placed the driving-gear, milling-feed, and quick-traversing mechanism for the column. The quick power traverse of the column has a speed of 5 ft. per minute. The driving-cone has six steps for a 4-in. belt, and is strongly back-geared, giving twelve changes of speed, ranging from 2 to 200 revolutions per minute, and has ample

power for boring up to 24 in. diameter. A platen is placed in front of the column, convenient to the spindle, for the operator to stand on.

A horizontal boring and drilling machine made by the Newark Machine-Tool Works is shown in Fig. 2. The work is bolted to the compound carriages which are shown directly under the boring-bar, the work being set square by the top surface and the edges of the carriage. The carriages can be moved either across or along the movable table, which is shown supported by the two large screws. The table can be lowered or raised from the side or at the end, as desired. A yoke of great strength braces the table, and serves as a bearing for the bar, or boring-arbor. The boring-bar is fed by a rack and pinion; and it is held by a friction-clamp, so that, by easing the clamp and taking another grip, a very long feed can be obtained. There is a quick and slow hand-motion for the bar. The power-lift for the table is a feature peculiar to these machines. The lower ends of the table lifting-screws are carried by worm-gears threaded to serve as nuts. These gears take their motion from the worm-shaft, which is driven from the feed-shaft by means of the chain-gearing. In this way, the power from the driving-cone is used to lift the table, and this arrangement enables the workman to move the table without leaving his position, and, when the work is nearly set, he can throw the power-lift out of gear and make the delicate final adjustment by hand, using the slow-feed hand-wheel. The machine has self-acting feeds in both directions, without reversing the directions of the motion of the cone, and a range of feed from $\frac{1}{4}$ to $\frac{1}{80}$ in.

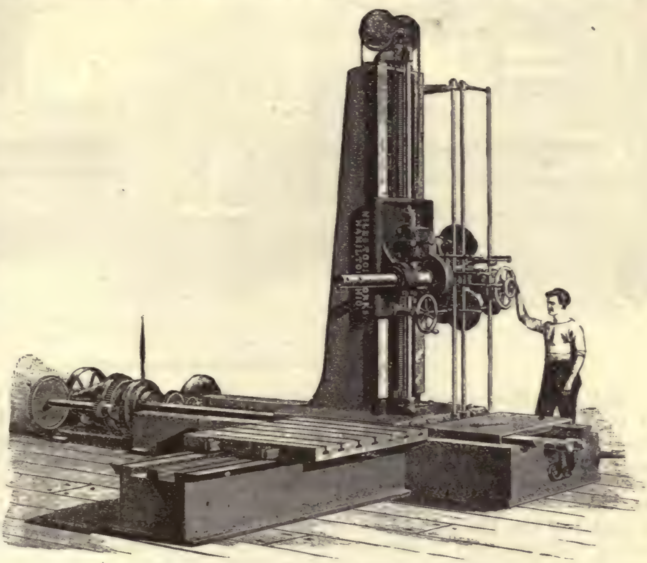


FIG. 1.—Niles horizontal boring-machine.

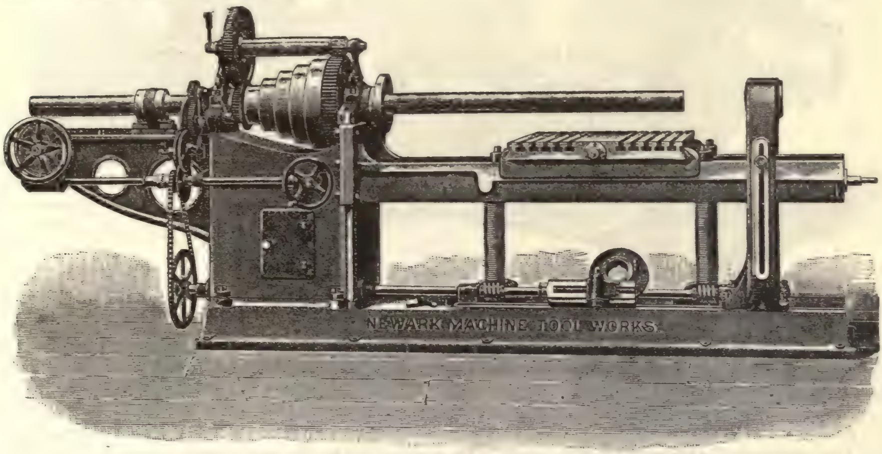


FIG. 2.—Newark Tool Works boring-machine.

The Nicholson Boring-Machine is shown in Fig. 3. It uses for a tool a cutter on a fixed bar, and passes the work by the cutting point; or, for large and heavy work, a traveling-head on a rotating bar with the work held stationary. To secure economy of time in setting, and to reduce the requirements for skill in the workman, the machine is provided with a broad flat table upon which to bolt the work. This table has a cross-feed, which secures the setting in the horizontal direction, and an up-and-down adjustment of the spindle locates the vertical. The heads are powerfully geared, the 40 and 50 in. sizes have eight and the 72 and 76 in. machines ten ranges of speed. Power applied to the cross-feed of the table admits of this machine being used for milling.

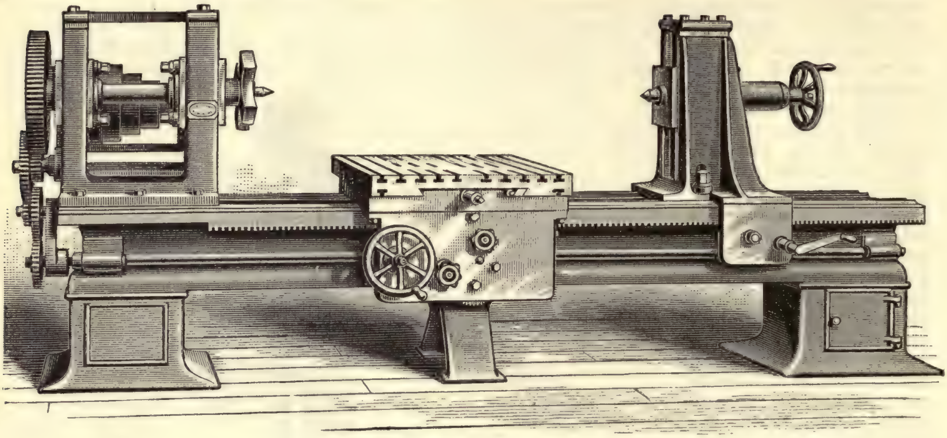


Fig. 3.—Nicholson boring-machine.

Cylinder Boring and Facing Machine.—Fig. 4 shows a machine built by Pedrick & Ayer, of Philadelphia, for boring cylinders up to 25 in. diameter. The boring-bar is solid forged steel, the screw is of steel with bronze thrust-bearings. The bar can be slipped through the bearing and gearing, or left standing, while the tail-bearing or back pedestal is taken away and the cylinder is placed in position over the bar. The feed-casing is made to feed either way, and has two changes, to operate which it is only necessary to push in or pull out a pin in center of the hand-wheel. The facing-head can be readily placed on the bar as desired, and, if necessary, can be operated at same time the cylinder is being bored. The cutter-heads have a long bearing on the bar, and are arranged for four tools, that number being found by

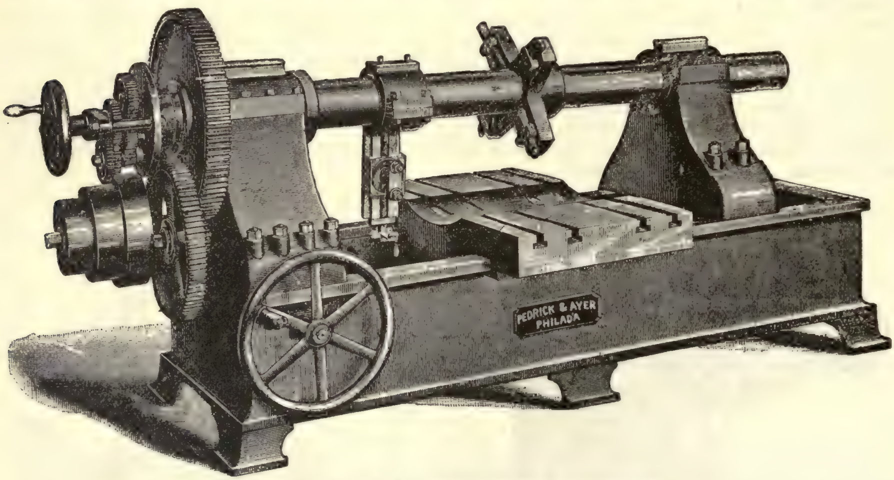


Fig. 4.—Pedrick & Ayer cylinder boring-machine.

experience the most desirable, as it distributes the stress or strain on the bar. The bed is movable on the shears, and is easily set in position by the hand-wheel at the forward end of the machine.

Duplex Boring-Machine.—Fig. 5 shows a machine built by Pedrick & Ayer for boring the two cylinders of a duplex pump at one time. The centers are made a fixed distance apart, to suit the centers of the pump-cylinders. The machine is therefore a special one, designed to be used upon but one size of pump. The platen is fed by a nut and screw driven by a $2\frac{1}{2}$-in. feed-belt.

Portable Cylinder Boring-Machines.—Fig. 6 shows a portable machine built by Pedrick & Ayer, of Philadelphia, especially adapted to boring out locomotive-cylinders in their places, by removing only one or both heads and piston. The back-head, cross-head, or slides need not be removed, unless so desired. On removing the piston and leaving the front head and stuffing-box, a small cone takes the place of the stuffing-box, and with proper adjustment at the front head the machine is ready for work; it is fed with a constant feed of cut-gears. The clamps or cross-heads are so arranged that they may be used conveniently on locomotive-cylinders of all sizes. The same bolts or studs that fasten the cylinder-head on are used to bolt

the bar supports also. Two rods are fastened to the ends of the cross-head that supports the bar in the cylinder and to an adjustable swivel cross-head on the end of the screw; these take the whole of the thrust and torsion strain of the bar. It makes no difference which position the bar is in, the end thrust is always in line with it, causing it to cut steady, smooth, and true. The feed can be thrown out of gear at any time, and the machine will also feed automatically. Another portable boring-machine, built by Pedrick & Ayer, is designed for reboring, in present positions, all makes and sizes of steam-engine cylinders. It is so constructed that the piece being bored serves as the bed or support of the bar. The cutter-heads are fed by a screw in one side of the bar, and are operated by the feed-casing on the end that contains the gearing, by changing position of which two changes can be made, slow feed for roughing out, and fast for finishing cuts. The feed is automatic and constant, or at the pleasure of the operator. The bar is driven by a train of cut-gears either with a crank or belt for power

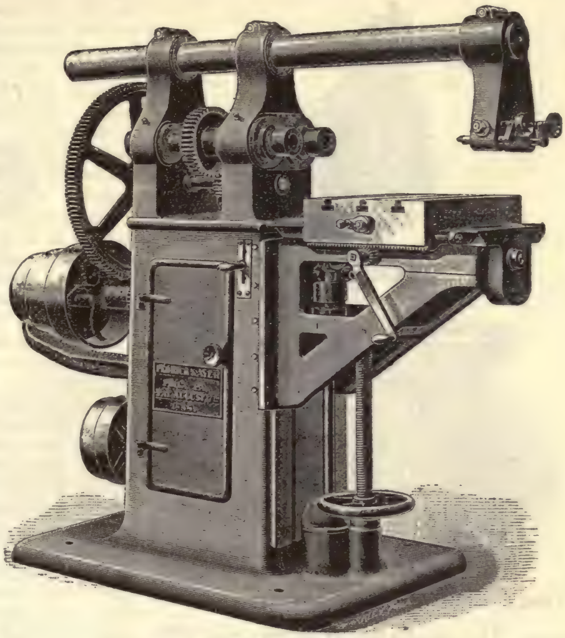


FIG. 5.—Duplex boring-machine.

II. VERTICAL BORING-MACHINES.—*Brown & Sharpe's Vertical Chucking-Machine.*—The term "chucking-machine" is commonly applied to a turret-lathe in which the revolving head contains a chuck for holding the pieces to be operated upon. It is also, however, sometimes applied to a vertical machine similar to a vertical boring-machine with a chuck rotating in a horizontal plane, and the vertical sliding head carrying a turret for holding a variety of tools. Such a machine is the Brown & Sharpe vertical chucking-machine shown in Fig. 7. The different tools in the turret-head are easily brought into operation, and, from their perpendicular position, allow the chips to fall through the center of the spindle of the revolving table to the floor, and thus avoid danger of trouble from the clogging of reamers, etc. The

FIG. 6.—Cylinder boring-machine.

machine has the capacity to bore a 4-in. hole, and receive a pulley 36 in. in diameter, $14\frac{1}{2}$-in. face, with hub 12 in. in length. It makes three cuts, and finishes by reaming without the removal of the tools or work. The revolving table is driven by a five-step cone for a 3-in. belt, and is geared 6 to 1. The steps of the cone are so graded as to make the cutting speed uniform for 5 different diameters of holes. The turret has four holes $1\frac{3}{4}$ in. in diameter, and is securely clamped in position. An adjustable dog allows the locking-pin to be withdrawn at any part of its upward motion. The turret-slide has a movement of 21 in., and an automatic feed which can be easily and quickly changed from the finest to the coarsest required; it has quick return by hand, and is counter-balanced by a weight inside of column.

Bullard's Boring and Turning Mill.—Fig. 8 shows a boring and turning mill made by the Bridgeport (Conn.) Machine-Tool Works. It is provided with a turret-head. Its capacity

is 38 in. in diameter and 27 in. in height. The table is $36\frac{1}{2}$ in. in diameter and has twenty changes of speed. The feed is by belt and has 4 changes. The turret-head is square in form, 10 in. in diameter, with four $2\frac{1}{2}$-in. holes. It will unlock automatically at any point, and is revolved by hand. The turret-slide can be set to bore or turn at any angle, and has a movement of 16 in., with trip at any point. Another form of mill by the same makers has two sliding heads. Its capacity is 37 in. in diameter and 29 in. in height. The table is $36\frac{1}{2}$ in. in diameter, and has twenty changes of speed. The feeds are automatic, and range from $\frac{1}{32}$ to $\frac{1}{4}$ of an in. in angular and vertical directions. Each head feeds independent of the other. The heads can be set at any angle, and carry the tool-bars, which have a movement of 18 in.

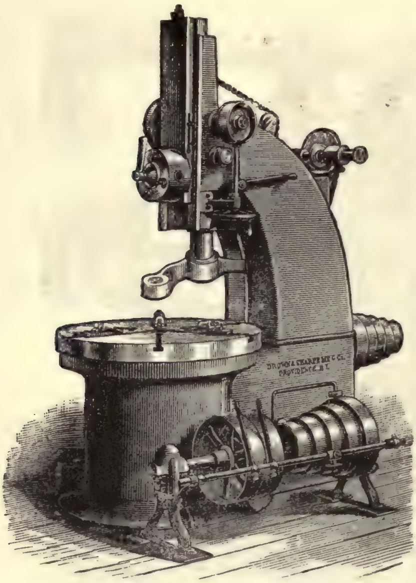


Fig. 7.—Brown & Sharpe's chucking-machine.

Chord Boring-Machine.—Fig. 9 shows a machine made by the Niles Tool Works for boring the holes in bridge-chords and I-beams. The machine is arranged with two independent heads on one bed, adjustable on the bed for varying lengths. The bed may be made of any length to suit. The two heads are complete in themselves, driven independently, and with all attachments, feeds, etc., for a complete boring-machine. The power is ample for boring four holes, punched 4 to 8 in. diameter, at one time, and the range of speed is such as to adapt the machine for drilling down to $1\frac{1}{2}$-in. holes. The two columns have both power and hand movement for adjustment on the bed. The heads have 18 in. reach, boring to the center of 36 in. They will take in under the cutter work 36 in. high. The spindle has 24 in. traverse. The range of work in length is from 5 to 50 ft. between centers. The feeds are by power, and are reversible up or down, and range from $\frac{1}{40}$ to

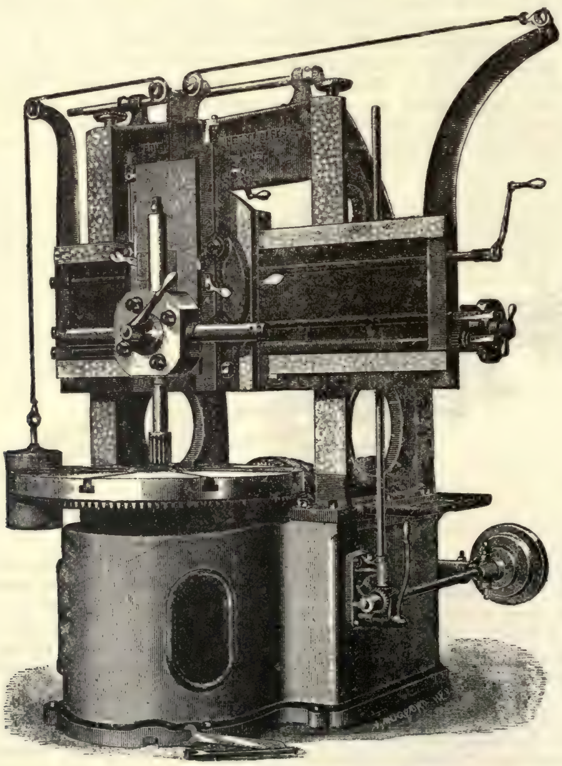


Fig. 8.—Bullard's boring-machine.

$\frac{1}{64}$ in. for heavy work, and coarser feeds for light work. The bed is formed of wrought-iron "I"-beams 15 in. deep. Two independent carriages for supporting work on the bed are provided.

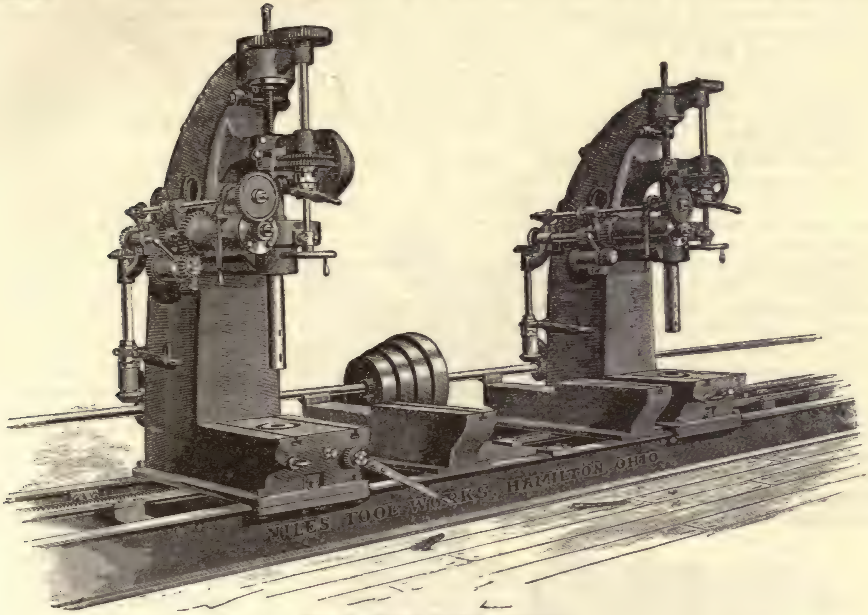


FIG. 9.—Chord boring-machine.

Fig. 10 shows a horizontal boring-mill built by the E. W. Bliss Co., Brooklyn, N. Y. This machine is especially designed for heavy work, though convenient for general shop use. By its use holes may be bored parallel to each other without resetting the work or traveling same

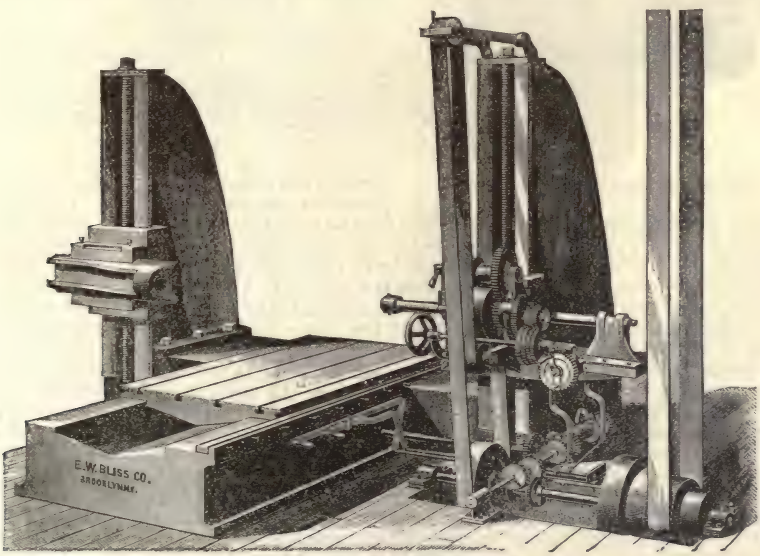


FIG. 10.—Bliss boring-machine.

during the process of boring. The table is moved to bring the work in position by a rack and pinion driven by power. The spindle carrying the boring-bar is of steel, $3\frac{1}{2}$ in. in diameter, and has a longitudinal feed of 30 in. It is carried by a head with 60 in. vertical adjustment upon a strong upright securely attached to the bed, and the cutter-end of bar is supported through a bush carried by the tail-block upon a similar upright on the left side of the machine. The head and tail blocks are raised and lowered together by means of screws shown, which are driven by power. To compensate for any possible variation in the two

vertical adjusting screws, a slight independent adjustment is provided in the tail-block, so as to bring the boring-bar perfectly true with the bed. The driving-cone pulley has four steps, and a heavy back-gear is attached to the spindle, giving eight speeds for the bar. The spindle is fed forward by a rack and pinion having four changes of speed, is driven by a worm-gear, and may be run back quickly by hand. The main spindle is driven directly by a belt from the floor-shaft, and the head may be raised or lowered without changing the length of the belt. The principal dimensions of the machine are as follows: Length of table, 7 ft.; width of table, 3 ft.; extreme width in clear between head and tail blocks, 8 ft.; vertical adjustment of heads, 5 ft.; floor space, 10 × 15 ft.; total height, 9 ft. The weight of the machine is about 26,000 lbs.

BORING-MACHINES, WOOD. From the primitive auger to the high-speed multiple gong boring-machine of the present day is a far cry; each year sees more advance either in the speed of work, in the quality of the work done, or in its range of dimensions and position, etc., until the catalogue of boring-machines alone would comprise quite a list, and a complete description of each kind made would fill a volume of no mean size. Suffice it if we select from a long list a few of the most typical or most ingenious and special for mere mention, in addition to the descriptions of construction and operation given in the former volumes of this Cyclopædia. In some boring-machines the spindles are run by gearing, and in others by belting. The latter permits higher speed of the spindles and smoother running. For certain classes of long boring, as in wooden pump-tube work and the making of porch columns, the cutter is carried on the end of a hollow pipe which has a worm rotating therein to carry out the chips; this being necessary in a horizontal machine, while a vertical machine would be undesirable by reason of the great length of work required to be done. Even such a simple operation as boring holes for pins, as in sash and door work, is now performed by an attachment to the double-arm sand-papering machine; the work being done by simply pressing the hand on the string, which drives the bit into the work, and on removing the hand the spring withdraws the bit from the hole. A very convenient machine for use in small shops, or where much large boring does not require to be done, is a portable boring-machine, Fig. 1, which is entirely self-contained, and may be fastened to a post and belted directly from the line shaft. There is a vertical spindle bearing the boring-tool and driven by a mitre gear, inclosed in a box housing which carries the bar for starting and stopping, also a counterbalanced lever for bringing the auger to the work. The boring spindle passes through one of the mitre wheels, so that it may be raised and lowered while rotating. A machine intended to meet the demand for boring to the center of large pieces is built by C. B. Rogers & Co., and differs from the usual types of small single-spindle boring-machines in having its spindle at a greater distance from the vertical post, so that holes may be bored in the center of the large piece. There is a stop-rod to regulate the depth of the hole bored, and also one to control the length of throw, thus doing away with the common adjustable collar of the spindle. The spindle is balanced. The table tilts for bevel work, and may be raised and lowered by a screw and hand-wheel in front. The guide may be reversed to the front of the table. A cabinet-maker's boring-machine for two or three spindles, made by C. B. Rogers & Co., has a square column like table cast in one piece, and upon which there is a plate which bears the front boring spindle-box, which, when they show two in number, are adjustable to and from each other by a right and left hand-screw. Where there are three, the center box is stationary and the others are adjusted to and from it by the screw and crank. The rear spindle-boxes have a swiveling motion on the table to accommodate the changes in distance between the front boxes; and they are driven by an endless belt which, passing from the main driving pulley at the lower part of the machine, goes over one boring-spindle pulley, down under an idle pulley (which has vertical adjustment to take up the slack of the belt as it stretches), up over the other boring-bar pulley, and down under the main pulley. Thus both the spindles run in the same direction, and their adjustment practically makes no difference in the tightness of the belt. Each of the mandrels to which the boring-bars are attached has a universal joint between it and the spindle. The table upon which the work is placed, and which bears a fence, is adjustable vertically in slides on the front of the machine, being controlled by a screw and hand-wheel. The table also has a horizontal movement to and from the bits. One very useful type of boring-machines, especially for car-work, has three or more vertical spindles, each bearing a different-sized bit, and each having a counterbalanced lever by which it may be drawn down to the work without much effort, and may be retired when the hand is taken from the lever. In such machines, there is little or no necessity for any lateral adjustment of the distance between the spindles, as only one is used at a time; but an important feature is that the ones which bear the adjusting bits are driven at slower speeds than the others. Where they are for heavy work, the table upon which the lumber rests is furnished with four rollers, and in improved machines of this type the timber may be pushed along on the rollers

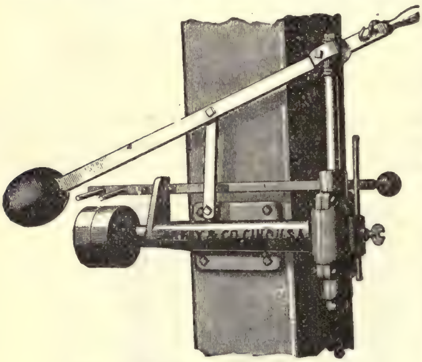


FIG. 1.—Portable boring-machine.

by hand, if not very heavy, or the rollers may be operated by a hand-wheel in front of the machine, thus giving also a fine adjustment. The feed-rollers may also be turned by a friction-power attachment from the countershaft. The belt is best endless, passing over the main driving pulley below on a horizontal shaft, then up over a horizontal pulley on a line with the spindle pulleys and at right angles with the main pulley, then over one spindle pulley, making a quarter twist to get there, then back and forth over idle pulleys and the other spindle pulleys, and down over another guide pulley to the main pulley below.

Universal Vertical Boring-Machine.—What is known as a universal vertical boring-machine, Fig. 2, is in some sense a misnomer, although it is a very useful tool. It is intended to bore both vertical holes and those which are inclined in a vertical plane. In one of the best

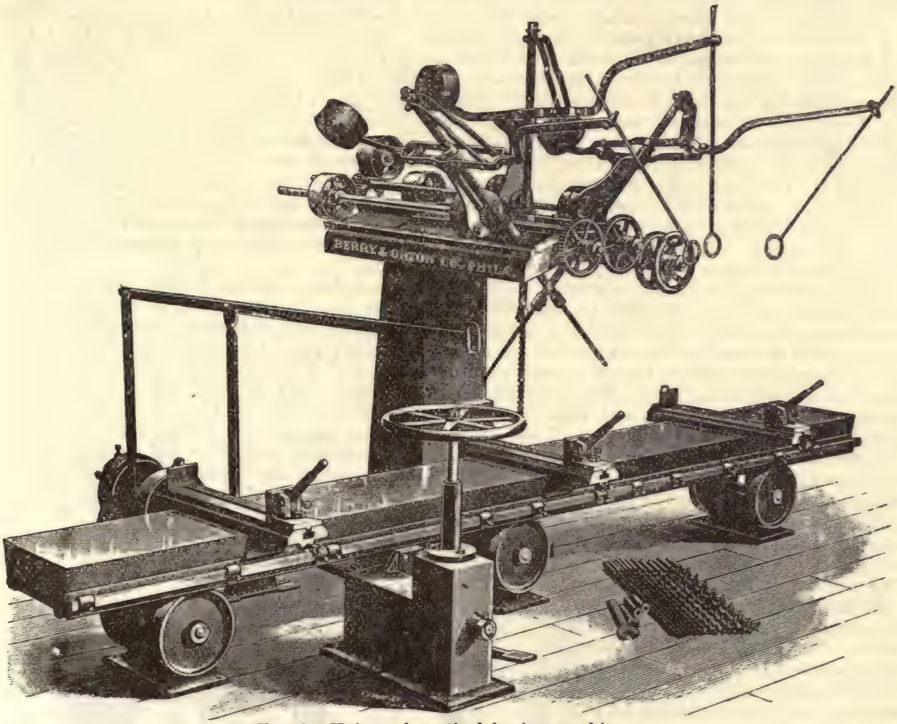


FIG. 2.—Universal vertical boring-machine.

forms, made by the Berry & Orton Co., there are three boring spindles, each of which has a movement of 24 in. back and forth in a horizontal plane and one in a vertical one of 18 in., and which can be set at an angle of 45° or less with the vertical. Each spindle, or any combination of two or of three, can be moved at once back and forth across the table by a hand-wheel in front of the horizontal bracket which carries them, and which is borne by a vertical clamp back of the table. Each of the boring spindles has a quick return, and is advanced to the work by a counterbalanced lever. The table to which the work is attached is made of glued-up strips of wood, veneered top and bottom with hard Southern pine, and may be of any desired length. It has on its edge a number of stops for duplicating work without the expense of laying out; and on the top a system of bolsters and clamps that take in 24 in. in width, to receive and fasten the timber that is to be bored. The table is mounted on a system of rolls 12 in. in diameter, and about 6 ft. apart, borne on uprights fastened to the floor. The motion of the table is by hand or power, through a feed-stand and shifting bar; the rate of feed by power being about 200 ft. per minute.

An Eight-Spindle Vertical Gang Boring-Machine, made by Fay & Co., of Cincinnati, has largely revolutionized the system of boring in car-shops. Originally in boring truck timbers it was necessary, where there were eight holes to be bored through a timber at one operation, to put it on a machine that would bore only three to four holes at a time, and as the timbers were about 14 in. thick, the holes could only be bored straight through by first boring half through the timber from one side, then reversing the stick and boring holes from the opposite side, to meet the others. The eight-spindle machine, which has an automatically raising table, enables the operator to bore the holes entirely through a timber of this thickness in a perfectly straight line. The operators place a stick upon the table and bore the necessary holes all at one time, thus effecting a great saving in handling the timber and in the time taken up.

The multiple gang boring-machine, designed for the special work of boring a large

number of holes at one operation without the necessity of laying them out, has a table, back of which there are ranged eight arbors, each carrying a boring tool. These spindles run in frames, which are gibbed to a connected gateway, and are vertically adjustable by a screw to each. The arbors have lateral adjustment also. Beneath the table and parallel with its length there is a horizontal drum, and the belt which drives all the boring-arbors runs from this over one driven pulley, then down under the drum, up over the second driven spindle, and so on until it has passed over all the pulleys; then it passes back lengthwise of the table by guide pulleys, so that there is but one belt to be laced, and no difficulty as in maintaining eight separate belt tensions. The spindles being set at the proper distance apart and at the proper heights, no adjustment is necessary. Eccentric clamps on the table hold the work. The table has lengthwise traverse on V-slides by a hand-lever.

The Bentel and Margedant Rake-Head Boring and Routing Machine has 20 spindles, which can be adjusted laterally to the required distance apart. The work is clamped to the table by four eccentric clamps, the handles of which are in the front of table, standing straight up. These clamp the work against a fence, which is bolted to the top of the table by T-slots. The face of this fence is lined with wood, so as to protect the points of the bits when cutting through.

The table is balanced, and has a continuous vertical reciprocating motion given by a crank and double levers in front of the machine. The crank has an adjustable throw to vary the length of mortise, and is driven by means of the pulley shown at the extreme right of the machine. The connecting rod also has an adjustment to bring the mortises into any position on the stick. The feed is operated by means of double lever and two vertical rods. These rods connect with two right and left ratchet-pawls, thus producing a continuous feed, which may be varied to suit the requirements of the work. The table is fed in by racks and pinions, and is geared at four points to get a parallel movement.

In operation, the work is clamped to the table, which keeps up its vertical reciprocating movement, and is not stopped to place the work. The feed is then thrown in by lifting a hand-wheel in front; this engages a worm and gear which feed the table forward automatically, until it has traveled in against an adjustable stop, when the feed is tripped off and the table returns automatically by means of a weight, and is ready for another piece. The machine is claimed to make 1,200 mortises 1½ in. long through 1 in. hard wood in an hour, leaving the mortise smooth and free from chips. It can be arranged for making a tapering mortise or to mortise lengthwise of the material. The makers state that it has mortised 150,000 holes through 3-in. sugar lumber without breaking a bit. For use as a multiple boring-machine, augers are substituted for the routing bits; the feed-belt at the right is stopped, and the one at the left which drives the cone is started, and the work clamped to the table, the same as for routing. The table is fed forward by pressing a foot-treadle; this is accomplished by a pair of driven friction-rolls, which grasp the slack belt which is wound around a pulley in front. When the pressure is removed, the table returns by means of the weight formerly described, which comes below the floor. The machine, when once adjusted for any particular piece, will turn out any number, all alike, without laying off.

Boxing Machine: see Wheel-Making Machines.

Box Tool: see Screw Machines.

BRAIDING AND COVERING MACHINES. Braiding machinery is employed for making plaited fabrics, either flat or round, such as are used for braids and other trimmings, wicks, fish-lines, shoe and corset laces, curtain-cords, etc. It has also of late years found a very important employment in the manufacture of the covering for electrical wire. The general principle of braiding-machines follows closely the idea of the old May-pole dance, in which each of the dancers, holding a ribbon attached to the top of the pole, moved around one another, in and out, until the ribbons were braided or plaited up and down the length of the pole. The various strands of the braid or covering are applied to a wire as a central core by mechanism, which imitates substantially the movement of the dancers. Covering or armoring machines are used on applying the non-braided insulating envelope of electric conductors.

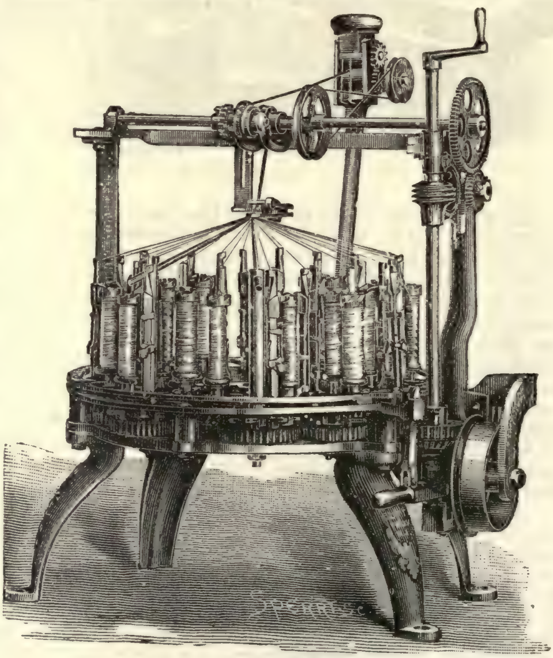


FIG. 1.—Braiding-machine.

Braiding-Machine.—We illustrate in Fig. 1 a machine intended for the manufacture of flat braids, and in Fig. 2 the carrier of that machine, manufactured by the New England Butt Co., of Providence, R. I. The mechanism of Fig. 1 consists of a series of gears meshing into one another, and provided with horns or lugs on their upper surfaces. These gears are mounted on a circular bottom plate. Above the bottom plate is a top plate, having openings or recesses in form corresponding with the periphery of the gears, and through this plate extend the carriers. Lugs on the bottom of the carriers extend down through the plate, and between the lugs on the gears, which in their rotary motion propel the carrier along the groove of the top plate which directs its course from the outer to the inner curve, a corresponding carrier on the other side of the curve going in the opposite direction, and at the intersection of each run crossing each other, thus forming the stitch. The carrier or bobbin-holder (Fig. 2) is provided with a spindle, *A*, for holding the bobbin, and a stem, *B*, for the weight and latch. The thread from the bobbin passes through a hole in the stem, and under a weight, *C*, which slides on the stem, then through a hole in the top of stem, and thence to the braiding-point. The weight acts in a fourfold capacity. It takes up the slack thread produced by the carrier, passing from the outer to the inner run. It makes a tension on the thread to braid tightly or loosely as may be required. It automatically stops the machine. The thread passing under the weight holds it suspended on the stem, and the breaking of the thread, or the running out of a bobbin, allows it to drop to the bottom of the stem, where it comes in contact with a point of the stop-rim, the contact operating a lever, which throws out the clutch and stops the machine. It regulates the supply of thread from the bobbins. As the thread is taken up in the process of braiding, it raises the weight until it comes in contact with the latch on the top of carrier; the latch being provided with a nose-piece engaging with a ratchet on the top of the bobbin, the weight raises the latch, disengaging the nose-piece and allowing the bobbin to let off thread; this act releases the weight, which falls to its natural position, the nose of the latch again engaging with ratchet in the bobbin, and holding it until the motion is repeated. These carriers, provided with bobbins of thread as described, two to each gear, in their continuous movement in and out and past each other at the intersecting points, form at the center of the machine, and at a proper angle above it, the plaiting or braid. A pair of rolls, driven by gears and shaft connection with the main driving device, forms the feed or take-up of the braid, from which it is led into a receptacle, or wound on to a reel. When made for tabular braids, or for round fabrics, it will be seen that any article inserted into the center of the machine and into the tubular fabric thus formed will be covered with it. The size of the braid depends upon the size and number of threads, and can be carried out indefinitely, a machine of 300 carriers having been built and operated successfully.

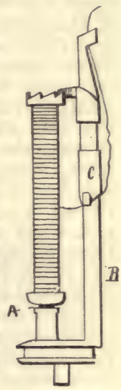


FIG. 2. Carrier.

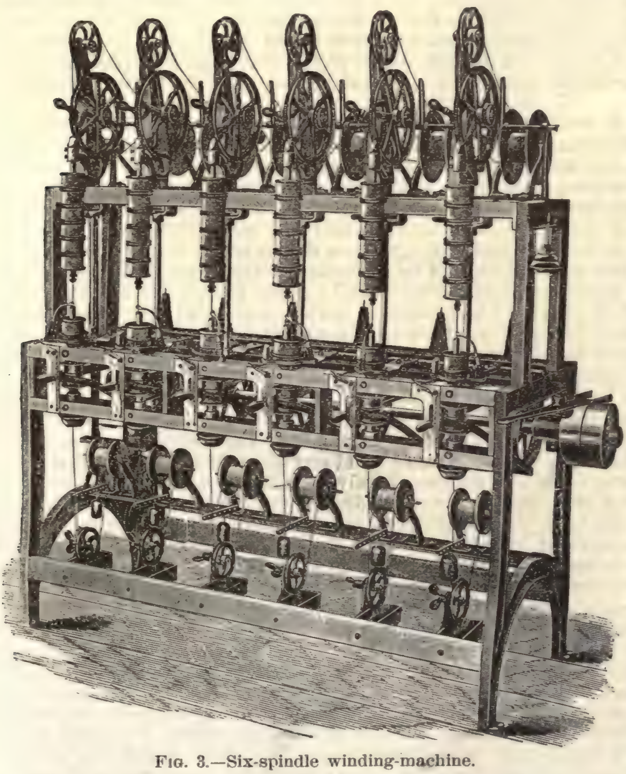


FIG. 3.—Six-spindle winding-machine.

Six-spindle Covering-Machine.— Fig. 3 represents a six-spindle winder, designed more particularly for covering electrical wires. The bare wire on the commercial spool or on a reel is placed on the standards under the machine (a tension regulated by the adjustment of the weight being applied); it then passes around a small sheave-wheel, which is so arranged that it can be lowered down into the pan for holding a solution of white lead or other insulating compound, if used, and to raise it out of the solution when the machine is not in operation. It then passes up through the spindle, which is driven by a quarter-turn belt on to a tight and loose pulley, the

loose pulley being chambered and filled with wool to retain the oil for lubricating. The wire then passes up through the disk on which the flier is fastened, with a counterbalance opposite. The spool is placed on the spindle, and the thread carried from it to the flier and under the drop-wire of the stop-motion, then up through the eye of flier to the winding-point, where it is fastened to the wire coming up through the spindle, in the top of which is the grooved guide and support for the wire when being wound. The guide can be finely adjusted for more or less tension and for the *lay* of the thread. The revolutions of the spindle which carries the spool and the flier around the wire at a high speed cover it uniformly and with the smallest fraction of insulation. Hanging over the thread and in the bottom of the flier is the drop-wire, which, when the thread breaks, or a spool runs out, drops, and extending through the disk, in its revolutions comes in contact with a latch holding up the starting lever, releasing it, when it falls, changing the belt to the loose pulley and stopping the spindle, each spindle being independent. The spool is slotted, and when it runs out of thread is raised just above the spindle and taken off sidewise; the wire passing through the slot, a full spool is taken down from the spool-holder above and placed on the spindle and threaded up, when the spindle is ready to go on again. The wire passing up through the tube or spool-holder passes around the feed-wheel and over the sheave down on to the reel. The feed-wheel is driven by connections of shaft and gearing with the spindle, making it positive; a variety of changes of speed being obtained by change-gears, which is made by a simple and quick arrangement. The hand-nut at the left of the feed-wheel is loosened, the wheel is raised up, throwing the gears out of mesh, and, after the change is made, the wheel is dropped back to engage with the gears. The hand-nut on the right of feed-wheel, when loosened, releases the wheel from the gear, and allows it to turn back to repair the wire or to mend a break.

BRAKES. *The Westinghouse Quick-Action Automatic Brake.*—In 1886 a practical test was made upon a train of 50 freight cars, to determine the applicability of existing brake apparatus to such a train service. This test was made upon the Chicago, Burlington & Quincy Railroad, under the direction of the Master Car-Builders' Association. It established the fact that, when the brakes were applied from the locomotive with full force, the reduction of air pressure in the train brake-pipe progressed gradually from the forward to the rear part of the train, causing the application of the brake upon the fiftieth car seventeen seconds later than that upon the first car. The retarding effect of the brakes applied to the forward cars, accumulating as it passed backward toward the unretarded rear of the train, was to close up the space between consecutive cars (due to lost motion in the couplings and compression of the draw-springs), and to produce severe and injurious shocks upon the rear cars and their lading.

It became evident that, to avoid such shocks and to give satisfactory results in this class of railway service, the application of the brakes upon successive cars must occur at such a rapid rate that no considerable retarding effect of the brakes shall be produced upon the forward part of the train before the brakes are in action at the rear end of the train. Experiments made by the Westinghouse Air-Brake Co., in the development of the quick-action brake, demonstrated that, with the closed coupling between cars and springs of such elasticity as those commonly employed in the draft-gear of freight-cars, shocks at the rear end of the train, of such magnitude as to injure cattle, could not be prevented, if the interval of time between the applications of succeeding brakes exceeded ·05 second; or the brake upon the fiftieth car must be applied not later than about 2·5 seconds after the application of that upon the first car. These conditions are fulfilled by the quick-action automatic brake, by the use of which the brakes upon 50 freight-cars may be successively applied in 2·25 seconds, or with an interval between the applications of succeeding brakes of but ·045 second.

The controlling element in this system is a discharge of air from the train brake-pipe at each car, by the operation of the triple valve, to cause the operation of the triple valve upon the next succeeding car; that is, a quick discharge of air from the train-brake pipe (either through the engineer's brake-valve, by the engineer, or at any point in the train), causing the nearest triple valve to operate, the others are successively operated by repeated discharges of air from the train brake-pipe, each triple valve responding to the discharge through the next preceding. The length of the main train brake-pipe, upon a train of 50 freight-cars, is 1,900 ft. The remarkable results attained, in the application of the quick-action automatic brake, will be appreciated when it is remembered that the elasticity of dry atmospheric air permits the propagation of an impulse or vibration, under the most favorable circumstances, only at the rate of 1,090 ft. per second. Sound—a most perfect example—requires 1¾ seconds to travel unimpeded through the atmosphere a distance of 1,900 ft. Yet the quick-action brakes are applied by an impulse which actuates a piece of mechanism, which in turn produces a second impulse, which actuates a second piece of mechanism, and so the impulse is repeated forty-nine times and caused to travel 1,900 ft., against the retarding influences of a comparatively small pipe, having a sinuous course and a vast number of irregular shapes and sharp turns, in the inconceivably short time of less than 2¼ seconds, or with a velocity 80 per cent of that of sound. Such results have been attained through a slight modification of the triple valve of the plain automatic brake (by which name the former Westinghouse automatic brake is now known), with the addition of a few supplementary parts. These modifications are such that they alter in no respect the functions performed by the triple valve of the plain automatic brake, and the additional parts operate only when a quick stop of the train is required.

Two distinct characters of performance of the triple valve may thus occur, the selection of

which is dependent wholly upon the rate at which the air pressure in the train brake-pipe is reduced for applying the brakes. The measure of the greatest rate at which the pressure in the train brake-pipe may be reduced, without operating the supplementary parts of the new triple valve, is that rate at which the pressure is reduced in the auxiliary reservoir, by the flow of air therefrom to the brake-cylinder—which latter is determined by the size of the passage connecting them. A rate of reduction of the air pressure in the train brake-pipe, materially greater than that of the reduction of pressure in the auxiliary reservoir, will induce the quick action of the nearest triple valve, which will be communicated to all the others, producing a full application of all the brakes; any rate, not greater, will cause the triple valves and brake apparatus to act in exactly the same manner as in the plain automatic brake, permitting the application of the brakes with any desired degree of force. To operate the quick-action automatic brake, greater precision is therefore involved than the plain automatic brake required, and a modified engineer's brake-valve is used for this purpose. The essential features of the quick-action automatic brake, differing from those of the plain automatic brake, thus lie wholly within the triple valve and engineer's brake-valve. While the end primarily sought, in the production of the quick-action automatic brake, was to avoid injurious shocks to the train, through application of the brakes, another result, of great importance, was incidentally effected, by causing the air, discharged from the train brake pipe through the triple valve, to pass into the brake-cylinder and to be retained there. This discharge of air from the train brake-pipe takes place before any considerable quantity of air can flow from the auxiliary reservoir to the brake-cylinder; the quantity of air discharged from the train brake-pipe is therefore dependent upon the relative volumes of the brake-cylinder and that portion of the train brake-pipe attached to the car. These relative volumes are such that the discharge of air from the train brake-pipe into the brake-cylinder, added to that from the auxiliary reservoir, increases the final pressure in the brake-cylinder and upon the piston 20 per cent beyond that when the cylinder receives air from the reservoir alone. Thus, in addition to preventing injurious shocks to the train, the quick-action automatic brake attains a considerably greater degree of efficiency by producing, almost simultaneously, upon all the cars of the train the greatest permissible retarding force.

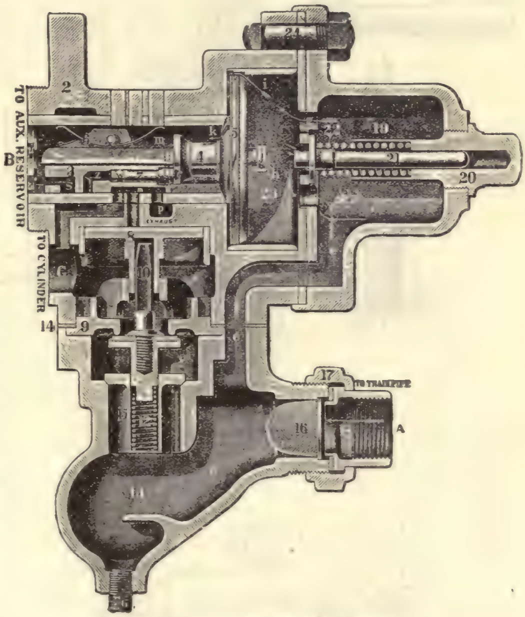


FIG. 1.—Quick-action triple valve.

The Quick-Action Triple Valve.—The parts which have been added to those of the plain automatic triple valve are the piston 8 (Fig. 1); the valve 10—which, normally, is held upon the seat 9 by the spring 12, and which is operated by the piston 8; and the check-valve 15, seated in the check-valve case 13. The port *t* is added to the plain automatic triple valve, which, when uncovered by the slide-valve 3, affords communication between the auxiliary reservoir and the chamber above the piston 8. This port is not in line with the ports leading respectively to the brake-cylinder and the atmosphere, but is at one side. The slide-valve 3 is made longer than in the plain automatic triple valve, and a corner is cut away, so that, when the piston 5 moves to its extreme position at the right, the slide-valve uncovers the port *t*, and air from the auxiliary reservoir is admitted to the chamber containing the piston 8.

The operation of this triple valve is as follows: The auxiliary reservoir having been filled with air at the pressure in the train brake-pipe, the brake may be applied by reducing the pressure in the train brake-pipe. The piston 5 moves to the right until stopped by the stem 21, and air begins to flow from the auxiliary reservoir to the brake-cylinder through the ports *w*, *z*, *r*, and *c*. If the pressure in the train brake-pipe is not reduced at a more rapid rate than that at which the pressure falls in the auxiliary reservoir, no further movement of the piston 5 takes place; if, however, the pressure in the train-pipe is rapidly reduced, the greater pressure in the auxiliary reservoir will force the piston 5 to its extreme position at the right, compressing the spring 22, and causing the slide-valve to uncover the port *t*. The pressure of the air thus admitted from the auxiliary reservoir upon piston 8 forces it downward, unseating valve 10, and so permitting the air in the train brake-pipe to lift the check-valve 15, and discharge directly into the brake-cylinder; the check-valve 15 then immediately closes and prevents the return of any air to the train brake-pipe. In this position of the slide-valve, also, the air continues to flow through the ports *S* and *r* from the auxiliary reservoir to the brake-cylinder until their air pressures come into equilibrium. As the

spring 22 may be compressed by a comparatively small difference in the air pressures upon the sides of the piston 5, a small reduction only of air pressure in the train brake-pipe, if quickly made, occurs before it is given access to the brake-cylinder through the check-valve 15. In all other respects the quick-action triple valve operates in the same manner as the plain automatic triple valve.

The triple valve is secured to and communicates directly with the auxiliary reservoir, while the pipe b, passing through the reservoir, affords communication between the triple valve and the brake-cylinder. The piston-rod 3 is a hollow tube, in which is inserted a rod having a

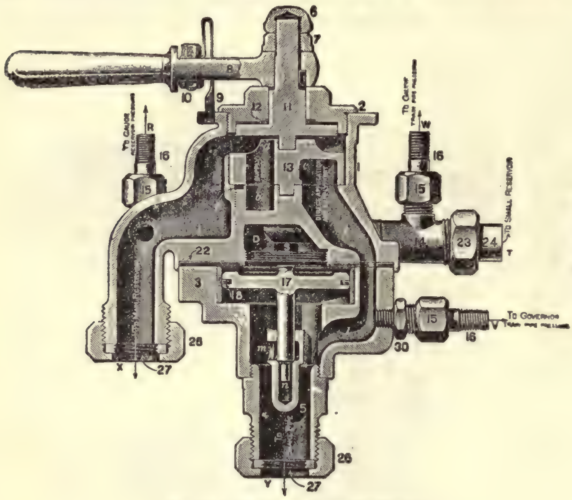


FIG. 2.—Brake-valve—Section.

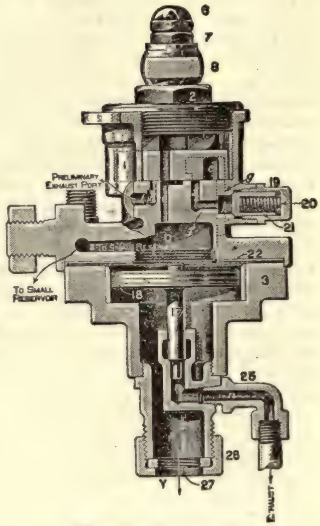


FIG. 3.—Brake-valve.

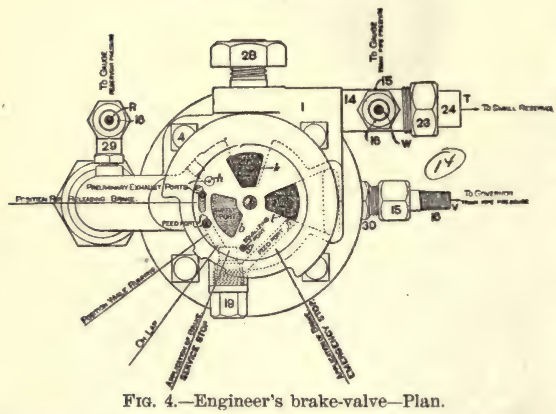


FIG. 4.—Engineer's brake-valve—Plan.

clevis at its outer end, which is attached to the lever. Its outward movement applies the brake.

The Engineer's Brake-Valve.—This valve has four distinct functions: First, to establish direct communication between the main storage reservoir and the train brake-pipe, for releasing the brakes; second, to maintain the required air pressure in the train brake-pipe and auxiliary reservoirs, while also maintaining a certain greater pressure in the main reservoir, to make sure the release of all the brakes after an application; third, to permit the escape of air from the train brake-pipe at a fixed rate, for all ordinary applications of the brakes; fourth, to cause a rapid discharge of air from the train brake-pipe, to secure the quick-action in an emergency application of the brakes. Figs. 2, 3, and 4 illustrate the brake-valve. The pipe from the main reservoir is attached at X; the train brake-pipe at Y; at T a small reservoir is attached, which merely serves the purpose of giving increased volume to the chamber D. A rotary valve 13 (the lower face of which is shown in Fig. 8) is operated by the handle 8. The piston 17, having a stem formed into a valve at its lower end, is subject to the air pressure of the train brake-pipe upon its lower face and to the air pressure of chamber D upon its upper face. The rotary valve 13 has two ports, a and j, passing through it, and two cavities, c and p, in its lower face. The seat for valve 13 has a cavity b, a large port k and a small port h, both leading directly to the atmosphere, two ports, e and g, leading to the chamber D, a large port l, leading to the train brake-pipe, and a port, f, leading to the port l, and in which is a valve 21. The different positions for the handle 8 are defined by projections from the valve-casing, shown in Fig. 4, which are encountered by the spring 9 from the handle, and offer sufficient resistance to the movement of the handle to mark the positions.

The operation of this valve is as follows: The handle 8 being placed in the release position, the air passes from the main reservoir, through the port a, cavities b and c, and port l, to the train brake-pipe, and releases the brakes. At the same time the air also passes through the ports j and e to the chamber D, thus placing piston 17 in equilibrium. The handle 8

Summary of Results of Tests, with 50-Car Train, in October, November, and December, 1887.

Description of Tests.—1. Emergency stop, train running 20 miles an hour. 2. Emergency stop, train running 40 miles an hour. 3. Applying brakes while train is standing still, to show quickness of application. 4. Emergency stop, with passengers aboard; speed, 40 miles per hour. 5. Service stop, and time of release. Showing the kind of stop made when a sudden stop is not necessary, and how promptly the brakes can be released. 6. Hand-brake stop, made at 20 miles an hour, with five brakemen at their posts (at Buffalo there were seven brakemen). 7. Breaking train in two. All the above stops were made with the braking power so low that it would not slide the wheels of empty cars in regular service. By using greater power, quicker stops could be made, but there would be more or less sliding of wheels, and it was not thought that the advantage gained would be enough to make up for the damage done in freight service. 8. Train running 20 miles an hour; the brake leverage having been increased to give the quickest stop possible. 9. Train running 40 miles an hour; leverage as in No. 8. 10. A train of 20 freight-cars and a train of 12 ordinary passenger-coaches were run alongside of each other, on parallel tracks, and the brakes applied at the same time. This test showed the relative stopping power of the old and the new brakes.

PLACE OF TEST.	Down grades, feet per mile.	FIRST.			SECOND.			FOURTH.			SIXTH.			SEVENTH.		EIGHTH.			NINTH.			TENTH.		
		Miles, speed.	Feet, distance.	Seconds, time.	Miles, speed.	Feet, distance.	Seconds, time.	Miles, speed.	Feet, distance.	Seconds, time.	Miles, speed.	Feet, distance.	Seconds, time.	Miles, speed.	Feet, distance apart.	Miles, speed.	Feet, distance.	Seconds, time.	Miles, speed.	Feet, distance.	Seconds, time.	Miles, speed.	Feet, distance.	Seconds, time.
St. Paul........	13·6	19	172	7	36	490	15	20 37	200 583	.. ..	..	......	..	25	100	20	109	..	37	327	..	..	.....	..
Chicago........	Level, head wind.	22	184	10	37	480	15	20 34	162 470	11 15	19	1,200	62	20	59	20	120	6	33	272	11	..	.....	..
St. Louis.......	52·8	20	176	11	36	507	18	35	502	17	21	2,115	128	23	61	20	109	6	38	377	11	..	.....	..
Cincinnati......	50	25	284	12	35	542	17	37	573	17	21	1,925	75	22	32	20	102	6	41	425	12	..	.....	..
Cleveland......	40	26	265	12	43	718	20	38	636	17	23	1,686	65	25	45	20	96	6	40	375	11	43	767	22 *
Buffalo.........	32·20	21	214	12	40	679	19	39	648	19	20	1,000	48	..	59	20	93	6	40	414	13	..	.....	..
Albany.........	35	20	158	10	36	560	18	37	580	19	20	1,342	60	..	180	19	78	5	40	358	12	..	.....	..
Boston.........	40	19	123	10	32	406	16	34	483	17	21	1,035	54	22	62	20	111	8	..	...	..	38	319 547	12 17
New York......	53	23	203	12	41	674	20	41	672	20	21	2,137	85	..	43	22	91	6	..	...	..	45	495 1,204	13 27
Philadelphia...	44	23	264	14	36	593	19	36	579	18	18	1,889	75	22	35	20	87	6	..	...	..	49	647 932	19 23
Washington....	52	19	159	10	42	694	21	42	718	21	20	1,643	67	23	58	21	81	6	40	359	11	..	.....	..
Pittsburg.......	47	20	194	11	40	649	21	40	673	20	20	1,720	72	..	..	20	95	6	..	...	..	45	494 890	14

Third Test.—In all cases the brakes went fully on within 2¼ seconds.

* Passenger-train only. Compare with freight-train in test No. 9.

Fifth Test.—The brakes were released in all cases in 4 seconds, and at Boston in 3 seconds.

is then moved to the position for running. Cavities *b* and *c* are thus separated, and the air from the main reservoir now has to pass to the train brake-pipe through ports *j*, *f*, and *l*. To pass through the port *f* the valve 21 must be forced from its seat, and, it being seated

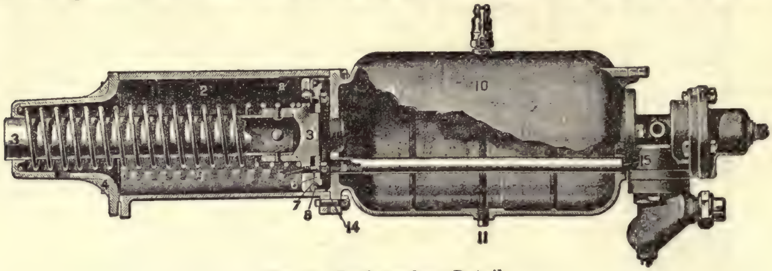


FIG. 5.—Brake-valve—Detail.

by the spring 20 of the proper resistance, a proportionally greater pressure is thus carried in the main reservoir. In this position of the handle, the piston 17 remains in equilibrium, the train brake-pipe and chamber *D* being in open communication, through port *l*, cavity *c*, and port *g*. Figs. 5, 6, 7, 8 show parts in detail.

To apply the brakes for any ordinary purpose the handle 8 is moved to the position for "service stop." All communication with the main reservoir is thus destroyed, and the air in chamber *D* is cut off from the train brake-pipe. The cavity *p* of the rotary valve 13 connects ports *e* and *h*, and air from the chamber *D* discharges to the atmosphere. A pressure gauge, connected to the chamber *D* at *W* indicates when the pressure has been sufficiently reduced by the discharge of air, and the handle 8 is then moved back as far as the position

FIG. 6.

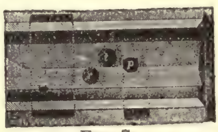


FIG. 7.

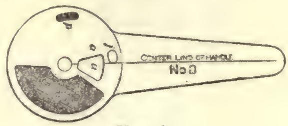


FIG. 8.

Brake-valve—Details.

"on lap." Here all ports are covered. Accompanying the reduction of pressure in chamber *D*, the equilibrium of piston 17 being destroyed, it is forced upward by the greater pressure in the train brake-pipe, and the port *n* is opened. The aperture of the port *n* is so gauged that the air is discharged from the train brake-pipe through the ports *m* and *n* at such a rate that the brakes are all applied gradually and uniformly. The discharge of air from the train brake-pipe through the port *n* continues until the reduced pressure becomes a little less than that remaining in chamber *D*, when piston 17 is forced downward and cuts off further discharge from the train brake-pipe. The volume of chamber *D* being constant, the reduction of pressure invariably corresponds to the quantity of air discharged from it, without reference to the volume of air in the train brake-pipe; the manipulation of the brake-valve, to apply each brake with any particular force, is the same, therefore, for trains of any length.

To effect a quick stop the handle 8 is moved directly to the position for "emergency stop." The cavity *c* then connects ports *l* and *k*, and, a large direct avenue for the escape of the air from the train brake-pipe being presented, a violent reduction of pressure occurs, causing the quick action of the triple valves and a sudden, full application of all the brakes.

On page 89 is given a tabulated statement of the results of a series of tests of the quick-action automatic brake upon a train of 50 freight-cars.

Bran Duster: see Milling Machinery, Grain.

Breaker: see Coal-Breaker, Ore-Crushing Machines, and Rope-Making Machines.

BRICK-MACHINES. Three classes of machines for the manufacture of bricks, tiles, etc., may be distinguished:

1. Soft-clay or sand-molding machines. The clay is taken from the bank, mixed with water, and thoroughly tempered in the machine, and pressed into molds, which are then taken from the machine, and the brick spread on the yard to dry, or put on pallets and dried in racks or artificial driers.

2. Die-working machines, making brick from tempered clay stiff enough to allow hacking direct from the machine. The clay is ground and tempered by the machine, and is pressed out through a die in the form of a bar. It is then cut into brick of the desired size by means of strong steel wires. Die-working machines may be divided into two sub-classes: (*a*) Auger machines, in which the clay is continuously moved out by means of a rotating auger; and (*b*) plunging machines, in which the clay is pressed out by the reciprocating motion of a plunger.

3. Dry-clay machines, which make brick from finely pulverized dry clay. This last type of machine is adapted to a comparatively small proportion of clays, and is best suited for the manufacture of pressed brick for the fronts of buildings.

As to the relative merits of the various processes of brick-making, opinions differ widely.

The adherents of the soft-clay process claim that the so-called "soft-mud" brick are not liable to crack or warp in drying, or check in burning; that they are cut easily with the trowel; that the sand surface forms an excellent ground for mortar; that all portions of the brick are equally dense, not having an external shell that is extremely hard and liable to flake off, leaving the porous interior to waste away. It is also claimed that they are much less difficult to burn, and, when well made and burned, if of good material, have no superior for strength and durability. Against the stiff-mud or wire-cut machines, the soft-clay adherents urge that the brick produced by them needs repressing; that they are not usually square, and that the ends are more or less ragged. It is also insisted that the clay being forced through dies stiff enough to handle at once, the center of the stream or column moves faster than its surface, and arranges itself in layers or laminations, making the brick very unsuitable for cutting by the mason, and liable to flake.

As against the dry-clay process, it is claimed that it is not possible to construct a dry-clay machine that will exert the tremendous pressure necessary to be continually given, and last for any reasonable length of time, without making it both clumsy and expensive; that there is no uniformity in density in the product, and that, after baking, the products become open and weak. The advantages claimed for the tempered-clay machines are, that they mix and temper the clay with water as they use it, without any additional handling, or without previously drying, rolling, or any other preparation whatever for ordinary clays, taking them just as furnished by Nature. The machines first, after tempering the clay, form it into a parallel-sided bar of the proper width and thickness for a brick, sand the surface, cut this bar in uniform lengths, and then deliver the bricks so molded and sanded in a condition sufficiently stiff to be immediately wheeled and hacked in the shade or on the drying-car.

The adherents of the stiff-clay machine claim that their apparatus does everything between dumping the clay into it and making the bricks ready to hack. The bricks, therefore, do not require to be sun-dried, and hence it is asserted that yards using such machines may run five or six weeks longer in a year than those using soft-clay molding-machines. It is pointed out that, if the soft machine-made or hand-made bricks be not dried enough to hack, in case of sudden rainy weather, they must necessarily be lost or damaged. The advantages and disadvantages of the different types of apparatus will be found fully set forth in the trade publications of the various brick-machine manufacturers, and need not further be discussed here.

There have been great improvements made not merely in the construction of brick-machines during the last ten years, but also in their workmanship. A leading manufacturer claims that it is "wholly a mistaken opinion that, because clay-working machinery must work in mud and grit, it should be rough and coarse," and maintains that the details of such machinery should be "as thoroughly studied, and the design as carefully worked into shape, as though it were a Waltham watch or a Corliss engine. Though it may seem useless refinement to work to templates with so much exactness on machinery that is to be covered with grease and dirt, and be exposed more or less to the weather and all kinds of rough handling, yet it is decided economy, durability, and freedom from expensive delays, to justify this care and expense."

The "New Haven" Horizontal Steam-Power Brick-Machine (Fig. 1).—This is an example of a soft-clay or "pallet-mud" machine. It is provided with a horizontal pug-mill, with a vertical pressing mechanism attached to the front, into which press-box the clay is forced by feed-wings on the tempering-shaft. The mold-ejecting carriage rolls on a mold-table (under machine), and is operated from a large press-gear by means of lever and connection shown on side of the machine. There are numerous features in the construction of this machine which are worthy of notice. The tempering-box has frame timbers, 8 in. × 8 in., strongly framed together, and is bound by three rods on each side, reaching from end to end. Vertical rods also bind it from top to bottom. At the front end, where the weight and strain are greatest, it is secured with strong iron braces and rodded in proportion. The bottom planks and side planks are removable. The rear end is a heavily ribbed casting, weighing 780 lbs., and is strong enough to stand any amount of back pressure that may be exerted at this point by the tempering-shaft. The lower front casting of the tempering-box weighs 790 lbs., is heavily ribbed on the inside, and has a babbitted bearing for the front end of the tempering-shaft cast on, with suitable oil-pipe cast in, reaching to the top. Immediately above is an upper front casting, which supports the steel crank-shaft, and which is held firmly in place by two side-braces, and is securely held down against upward pressure of the press by heavy rods on each side of the crank. The tempering-shaft is 4 in. sq., with a heavy steel collar shrunk on at the shoulder next to rear-bearing, to give a large back pressure-wearing surface. On the rear end of the shaft is a heavy bevel gear, 3 ft. 10 in. diameter, 6 in. face, which is driven by a clutch pinion on main shaft. These gears have only to drive the tempering-shaft as the press is driven by pulleys. As many flat or pitched tempering-knives and feed-wings can be attached to this shaft as are needed to properly temper the clay and feed the press. The press-box is 33 in. × 9½ in. inside. The surfaces are planed and lined with steel plates. It will be noticed that the steel cross-head attached to the pitman, and which moves perpendicularly in the plunger standard, exerts its pressure squarely on a broad steel press-plate that fits in the pressure-adjusting notches. The effect of this arrangement is to assure a firm, square movement of the plunger downward, and prevents liability to tilt and bring extra strain and wear on the guides. The pressing surface of the cross-head is 4 in. × 4½ in. The stroke of the plunger can be regulated by inches, from 3½ in. to 10½ in., full stroke, and pressure remains on while the mold is being delivered; or, by removing the press-plate, all pressing is stopped while the machine still runs. That amount of adjustment should be enough to accommodate

any degree of tempered clay. The means of relief in cases of stones or other obstructions consist in doors, shown in front of the press, which are held in place by springs, so adjusted that if an obstruction projects from any single brick that door will fly open and allow it to pass out, leaving the remaining five bricks in the mold perfect, or if the obstruction covers more than one brick it will open two or more doors and pass out. This arrangement prevents breakage and wear and tear on the molds. On the side of the machine just above the grip connection is a dash-pot with its plunger connected with the ejector-lever, which forms an air-cushion, to prevent jar on the return stroke. The mold-table is held in position by four

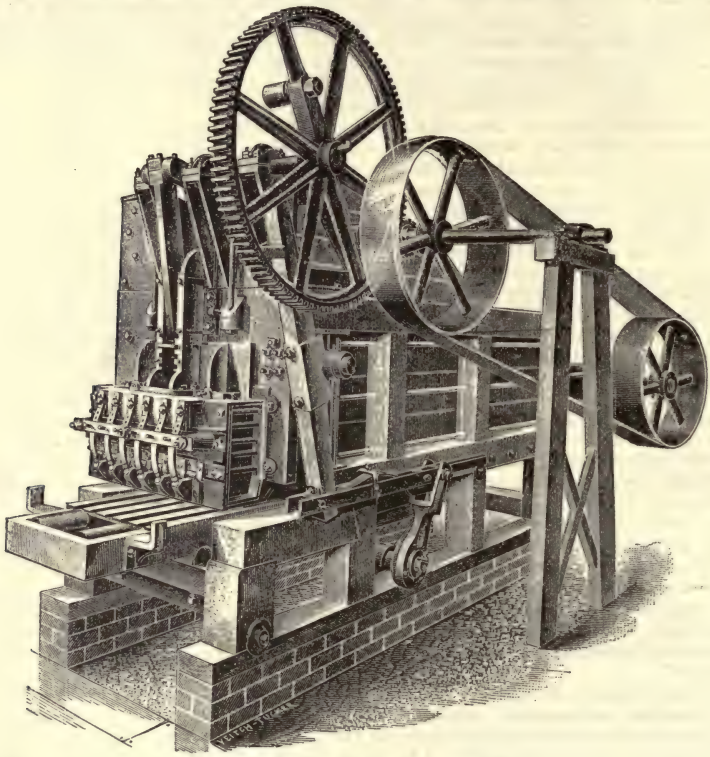


FIG. 1.—The New Haven brick-machine.

large steel screws that work in heavy iron cross-beams. The ejector-carriage is of iron, with wood buffer strip on the front to protect the molds from wear. Its four rollers run on an iron track on table. The carriage has a quick return motion, which allows plenty of time to insert the molds. Weight of machine, complete, is about 14,300 lbs., or a little more than 7 tons. In point of capacity, the machine is usually geared to make 13 molds per minute, which is 4,680 bricks per hour. For an output of 13 molds per minute the main driving shaft should run about 150 revolutions per minute. With stiff clay the power required for this output is about 25 horse. To produce 40,000 bricks per day requires a force of nine men and four boys.

The Chambers Brick-Machine (Fig. 2), manufactured by Messrs. Chambers Bro. & Co., of Philadelphia, Pa., is an example of an auger-class of stiff-clay machine. The clay is taken direct from the bank and dumped on the platform covering the machine at the side of a galvanized iron hopper that leads into the tempering-case of the machine, and mixed, when necessary, with loam, sand, or coal-dust; and the requisite amount of water being added to temper the clay to the proper consistency, the mass is shoveled into the hopper and falls into the machine. The hopper of the brick-machine proper is square, with circular corners, to prevent the clay from sticking in the corners, and is larger at the bottom than at the top, to prevent jamming of the mass. It enters the tempering-case at one side of its center line, so that the clay in falling meets the revolving tempering-knives as they are coming up. This keeps up an agitation of the clay in the hopper, and tends to prevent clogging and an irregular supply of clay to the tempering device. A small cast-iron roller is situated at the bottom of the hopper, and just above the line of tempering-knives and at the side toward which the knives move. Against this roller the clay is thrust by the tempering-knives as they cut through the solid mass of fine clay and lumps, and on to which the clay adheres; but as this roller turns around, say once in a minute, the impinged clay is carried within the path of the knives, and is carried off by them and tempered, thus effectually clearing the throat of the hopper. The tempering portion of the machine consists of a cast-iron conical case, in which revolves a horizontal shaft into which are set spirally, strong tempering-knives,

so that, as they pass through the clay, they move it forward. The clay being stiff, and not having much water on it, is not liable to slip before the knives, but is cut through and through, and thoroughly tempered, the air escaping back through the untempered clay, so that by the time the clay reaches the small end of the tempering-case it is ready to be formed into bricks.

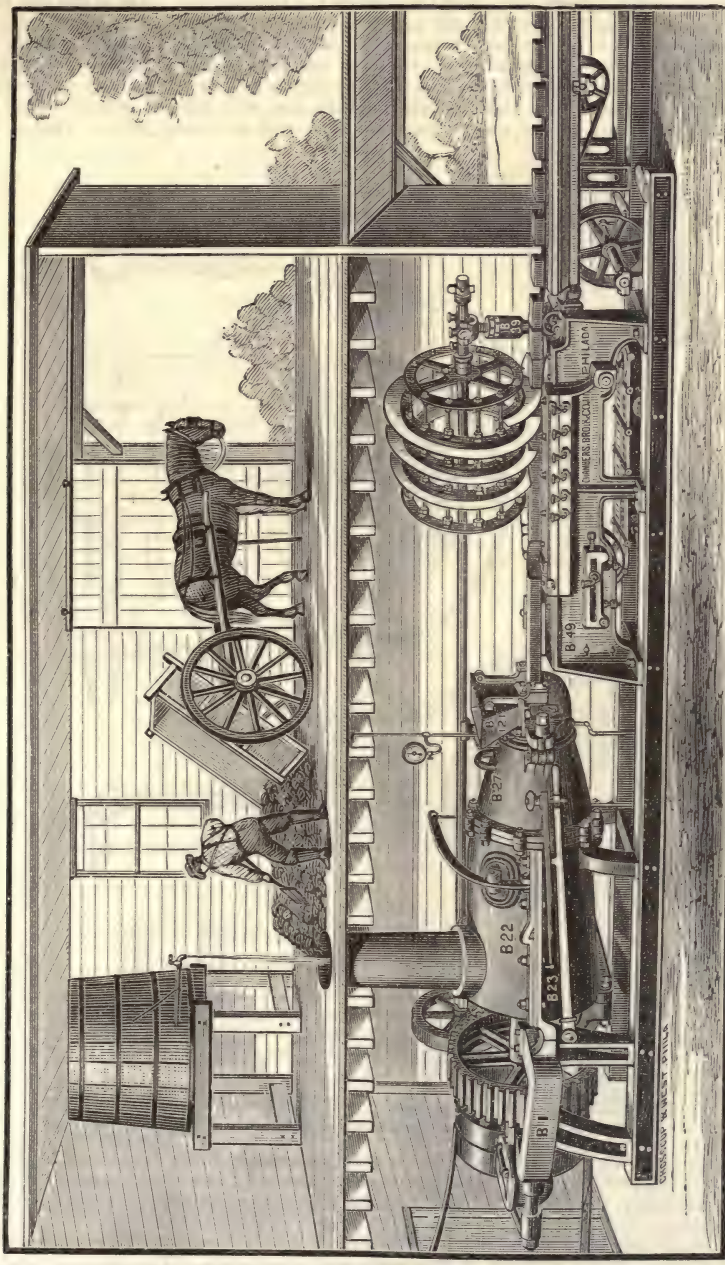


Fig. 2.—The Chamber's brick-machine.

On the end of the tempering-shaft is secured a conical screw of hard iron, which revolves in a hard-iron conical case, the inside of which is ribbed or fluted lengthwise, so as to prevent the clay from revolving in it, and is hard, to prevent wearing. The screw being smooth and very hard, the clay slides on it, thus becoming, as it were, a nut; the screw revolving and not being allowed to move backward, the clay must go forward, sliding within the screw-case. This operation further tempers the clay, and delivers it in a solid round column to the forming-die, which (Fig. 3) is held within the steam-heated former-case. The great difficulty experienced in machines expressing plastic materials has been to make the flowing mass move

with uniform velocity through all its parts. As the channel of a river flows faster than the shallow portions, or those near the banks, so does clay move through a die, the friction of the corners holding them back, while the center moves more freely. In the present machine this difficulty is overcome by the peculiar "former," which is so shaped as to facilitate the flow of the clay to the corners, and retard it opposite to the straight sides of the die, the projections being much larger opposite the larger diameter of the die (Fig. 3). For very wide and thin bricks the resisting projection is omitted wholly at the short diameter of the die, or at the edge of the bricks, the spreading of the clay outward to the edge, rather than into the corners only, being facilitated. By this means the angles of the bar of clay are re-enforced and made very solid and sharp, thus insuring square and well-defined corners to the bricks. The "former" is secured to the screw-case by a hinge and swinging bolt, so that it may be

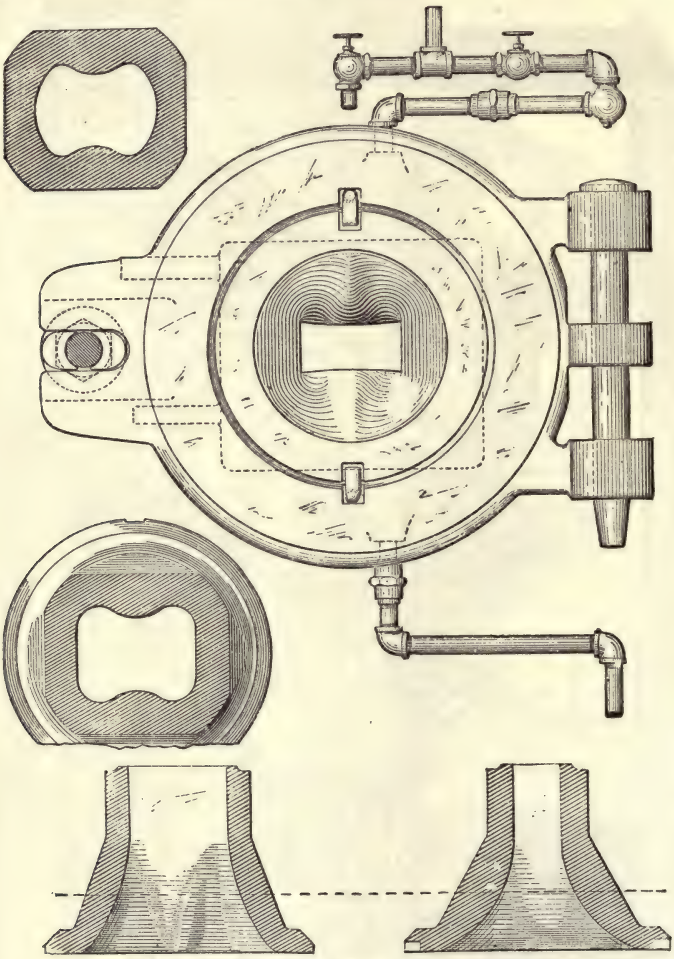


Fig. 3.—The Chambers brick-machine—the dies.

quickly swung open for the removal of stones. This swinging bolt is secured to the case by a pin of just sufficient strength to hold under normal conditions, and when undue strain comes from hard clay, etc., it yields, thus forming a safeguard against accidents arising from improper feeding.

As the bar of clay issues from the forming-die it passes through a small chamber filled with fine, dry sand, which adheres to the surface of the bricks. The surplus sand is kept back in the chamber by swinging elastic scrapers, which allow the bar to escape with its adhering sand. This sanded surface of the clay bar prevents the bricks from sticking together on the barrows or in the hacks, or on the drying-cars, and improves them in color when burnt. All clay has more or less stones in it, and as it is impracticable to pick them all out, there is a necessity of making some provision for their removal. If a stone is more than 3 in. in diameter, and does not lodge in the stationary lining of clay in the case, it will lodge at the entrance to the expressing screw, preventing the clay from issuing at the die, when a safety-valve is forced open, through which the stone may readily be removed. If a stone of less

diameter than the mouth of the screw passes to that point, it will go through the screw, the openings between the threads being less at the entrance than at any other point; so that a stone that once fairly enters can not lodge until it has reached the forming-die, where it will lodge if it is larger than a brick is thick, and prevent the proper flow of clay, causing the bar to split in two, or only part of the bar to issue; this forming-die being secured on hinges, it can be swung open and the stone knocked out, when the die is closed and the machine again started. Should an undue pressure be brought upon the machine from a stone lodging in the die, or the clay being too sandy or too stiff, there is a safety-pin holding the eye-bolt that secures the "former," which is cut off by the strain and the former opens, thus instantly and automatically relieving the machine.

The bricks cut from the continuous bar are separated and carried by an endless belt any desired distance, sometimes 200 ft. across the yard, from which the bricks may be wheeled to any point most convenient for "hacking," or loaded directly upon the drier-cars, as may be required.

The Spiral Cut-off (Fig. 4), employed in the Chamber's machine, is a thin blade of tempered steel, secured to the periphery of a drum, in the form of a spiral, the distance between the blades of which is that required for the length of a brick, and the projection of which gradually increases from nothing at its first end to the full width of the widest brick to be cut. This spiral knife runs perpendicularly in openings in the links of an endless chain, supported upon rollers, the chain being so formed as to support the bar of clay from the bottom and one edge; the clay is thus fully supported while being slowly cut off by the long drawing cut of the spiral blades in passing through the openings in the chain. The distance between the spiral blades being uniform, the lengths of the bricks are uniform. The ends of the bricks are cut smooth and square. The speed is controlled by that of the clay itself; hence, no matter how irregular the flow of clay from the die, the spiral runs in exact unison therewith, consequently the uniformity in the length of the bricks. This controlling of the speed of the spiral by the clay is so positive that it will run at any speed, from 3 to 100 bricks per minute, while the machine runs at its regular speed. In order that the spiral knife may not be affected by stones, the shaft to which it is secured is held in position by gravity and counterweighted, so as to adjust it with just sufficient force to compel the knife to pass through the bar of clay. When the knife comes in contact with any hard foreign substance, as stones, brickbats, or bones, its rides up on the obstruction, and, when passed, falls by gravity to its original position.

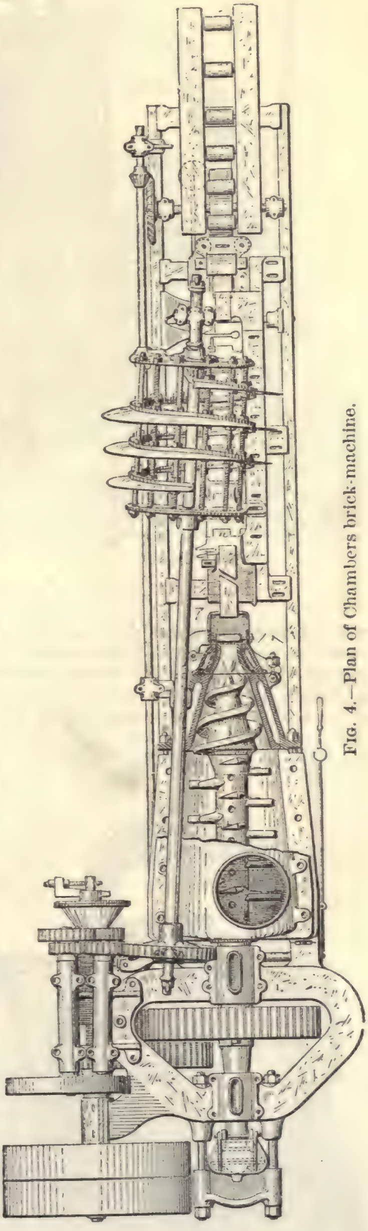


Fig. 4.—Plan of Chambers brick-machine.

The Penfield Plunger Brick-Machine (Fig. 5), manufactured by Messrs. J. W. Penfield & Son, Willoughby, Ohio, is an example of the plunger type of stiff-clay machine. The clay is fed into the drum or tempering-cylinder, in the center of which is a shaft filled with blades, which grind the clay and force it through a port-hole into the pressing chamber. A plunger device then presses the clay through the die, and on to the cut-off table. It is then cut into bricks by means of a suitable cutter-frame, strung with wires and operated by hand. The mechanical device used to propel the plunger is a steel cam, placed on the main shaft between the upper and lower bed-plates. It operates the rollers at the front and rear ends of a sliding frame to which the plunger is attached, giving it alternately a forward and backward motion at each revolution of the shaft. The machines are made either single or double workers—one cam doing the work in either case. The main shaft, cam, and friction roller are of steel, and the machines are built with proportionate strength throughout. In this machine, as in that last described, the clay is tempered and molded stiff enough to allow immediate hacking of the brick. Fig. 5 represents a Penfield machine capable of turning out 40,000 bricks per 10 hours, and having the following dimensions: Height of machine, 9 ft. 8 in.; length of sills, 6 ft.; width from out to out of sills, 3 ft. 10 in.; extreme

width, 6 ft. 6 in.; capacity, 40,000 bricks per 10 hours; estimated weight, 12,000 lbs.; speed of pulley-shaft, about 145 revolutions per minute; pulleys, 42 in. diameter, 10 in. face; machine is back-geared 42 to 1.

By a change of die in this machine, all shapes and sizes of bricks, especially those of ornamental patterns, can be made. The construction and arrangement of the die, therefore, form

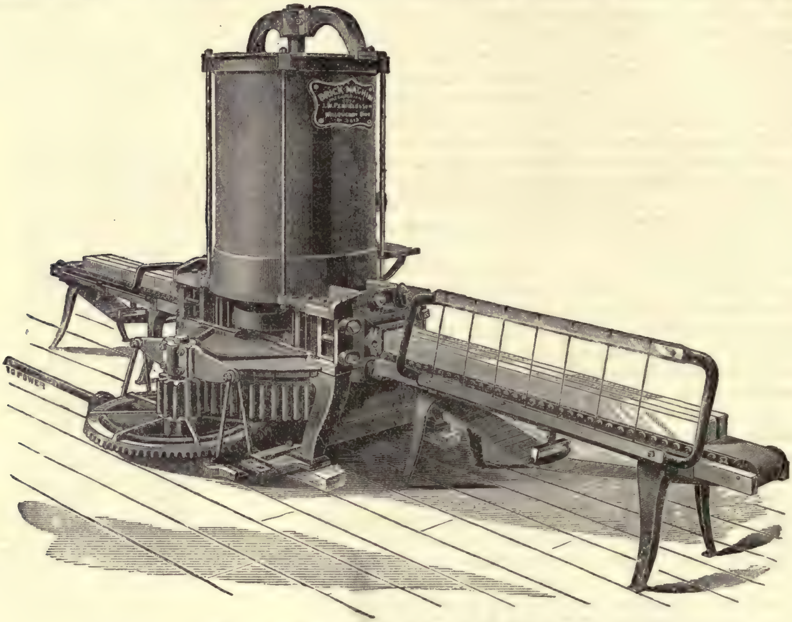


FIG. 5.—The Penfield plunger brick-machine.

a novel and important feature. The back or forming die receives and forms a bar of clay with rounded corners. The clay bar then passes through the finishing die, which is slightly square-cornered, and by means of this "slicker" and the process of lubrication the bar is finished and given corners accurately shaped. The lubrication is effected by water, by steam, or by both. For water lubrication the finishing die is set a short distance ahead of the back die, and water (or oil) is allowed to flow between the two dies and upon the clay bar. For steam lubrication the finishing and forming dies are bolted tightly together and packed. Steam is then supplied directly from the boiler to the clay bar. In cases where both water and steam lubrication are desired, two slickers or finishing dies are used, the one next to the forming die being arranged for steam connection, and the front slicker being water lubricating, each being operated respectively as already explained. Good results have also been obtained with a so-called "brass scale finishing" die in which the outer part of the slicker is an iron casting, into which is fitted a wooden lining, which in turn is lined with strips of spring brass. This slicker is provided with a large number of channels, conducting the water or steam from the outside of the slicker to the brass scales, thus lubricating the bar of clay effectively as it passes through the die. In still another form of die each corner of the bar of clay is lubricated separately, and by means of a brass plug at each corner the flow of steam can be regulated or entirely shut off from any one or more corners at any time desired. Thus, if one corner of the die becomes clogged, so that the steam does not reach the corner of the bar of clay, causing it to ruffle or tear, the steam can be shut off from the other three corners. This will allow the full head of steam to reach the corner which is clogged, blowing out the obstruction.

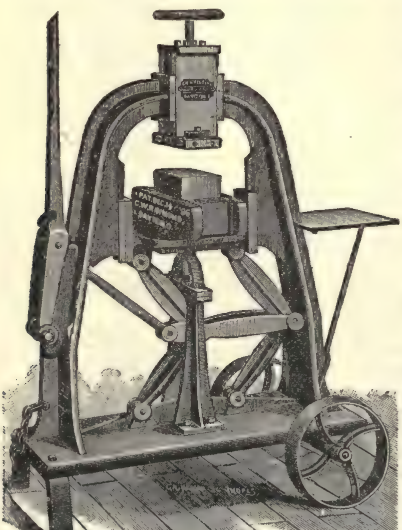


FIG. 6.—Hand brick-repressing press.

Brick-Repressing Machines.—Up to within a few years, the process of making ornamental bricks, tiles, etc., was carried on entirely by hand, requiring skilled labor, and producing but a few pieces of work per day. An example of a repressing hand-press, which will produce designs of the most complicated pattern, and manufactured by Messrs. C. W. Raymond & Co., of Dayton, Ohio, is given in Fig. 6. The dies, which are supported upon the fixed standard above, are made of finished brass; and as one die can easily be changed for another, the range of patterns possible is endless. The clay is first struck out by a machine, or molded by hand, in order to insure proper tempering and to get the requisite amount in block. After partial drying, it is put in the press, when a single stroke of the lever causes it to be molded into the desired form. As many as 2,000 blocks per hour can be made on a single press of this description. The large demand made by architects for ornamental brick for embellishment of the exterior of buildings has resulted in the construction of an automatic-power brick-repressing machine, which is constructed by the same manufacturer, and which is illustrated in Fig. 7. Here the brick, after being struck out by hand or machine, and allowed properly to dry, are placed on the feeding-table by an attendant, or run indirect from the off-bearing belt. They are then taken, by the mechanism of the press, fed into the die automatically, where they are subject to great and uniform pressure, which imparts to them sharp and well-defined corners and edges, after which they are discharged from the press automatically upon the endless vibrating-belt in a finished and perfect condition. Thence they are placed upon barrows or trucks by an off-bearer. Two men, or rather two boys, are required to operate it. The capacity of this machine is from 10,000 to 12,000 bricks per day. Not merely are brick-repressing machines adapted to the production of ornamental bricks, but it is fast becoming the practice to repress all brick used for paving purposes. It is claimed that paving bricks so repressed will not flake or laminate, nor crack by the contact of horses' feet. They may be made of any shape, and so as to present a uniform and smooth surface, and as a roadway, while their greater density causes them to absorb less fluids and gases.

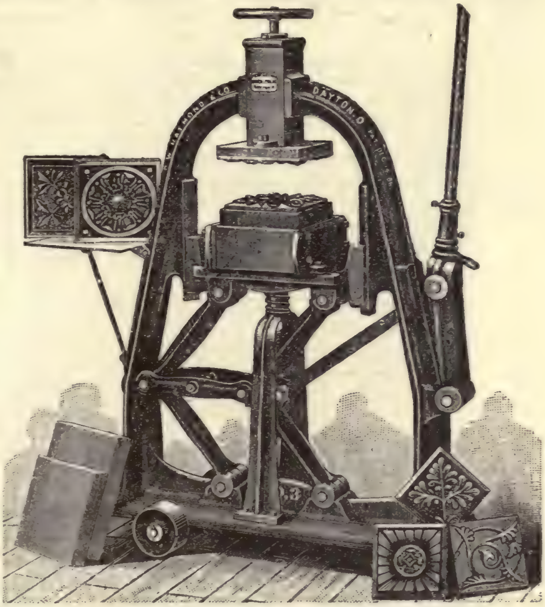


Fig. 7.—Power brick-repressing press.

Messrs. Chambers Bro. & Co. give the following method of making pressed bricks, using their machine. "To manufacture press bricks by our machine, we put on a die that will mold the bricks sufficiently narrow to drop into the mold of the press, and thick enough to make a press brick of the proper size. This can be done in five minntes. Then we use a very fine sand, largely impregnated with iron, baked dry and sieved, which is put into the sanding-machine, which coats the sides and edges of the brick all over, thus making a veneering of fine iron-ore and sand on their faces. These bricks are taken from the machine in the usual manner, loaded carefully on barrows designed for the purpose with their heads all even, then

Fig. 8.—Handling bricks.

their heads are rubbed with sand also (Fig. 8). Now they are wheeled to the "press-shed," where they are "hacked" close; that is, so as to prevent the air from passing between them, thereby keeping them at about the same consistency as when they were made, which is just right for repressing. From this close hack the bricks are taken and repressed in the usual manner; or, if a sufficient number of presses be used, or the machine runs slow, they may be taken and pressed direct from the barrows. This repressing brings the bricks to a mathematical precision as regards their size, surfaces, and angles, the flat or largest surface of the bricks being concave, for the purpose of allowing the edges to come close, so as to show a very thin joint when laid. We do not think the "skin" on the press-bricks molded in our machines usually so good as those molded in sand by hand; but where the clay gives "color," and not the molding sand, then the best color is obtained by repressing our machine-bricks direct from the machine."

Arrangement of Brick-Yard Machinery.—Fig. 9 represents a ground-plan, showing the arrangement of pits, single-worker machine, boiler and engine, etc. This plan is made to show the arrangement of pits and machines, where crusher and elevator are used, or where it

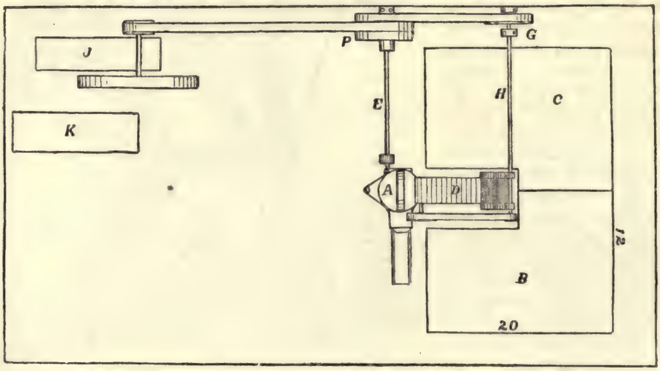


FIG. 9.—Plan of brick-yard.

is found desirable to simply use the elevator. *A* represents the machine placed midway between the pits *B* and *C*. The pits are 12 ft. long and 20 ft. deep. The clay-crushers are placed between the two pits, and about half-way back. By this arrangement the clay is always reasonably convenient to the clay-crusher, and one pit can be filled and soaked while the other pit is being run into brick. This is by far the best plan upon which to operate the machine. The machine does not in this case require moving, and the clay can be much more thoroughly soaked, and fed into the crusher with less labor and expense than it can be thrown into the machine. One man can feed the crusher as easily as two can feed the machine. Where a crusher is not used, an elevator, represented by *D*, is arranged to run over the partition between the pits. As the pits are 12 ft. wide and 20 ft. long, the shovelers are never at a great distance from the carrier, and the saving of one man's labor can be effected by this arrangement, which will pay for an elevator, or even a crusher, in a very short time. *E* represents the tumbling-rod which transmits the power to the machine. At *P* the pulleys are placed, which receive the belts from the engine *J*. *K* represents the boiler, and *G* the crusher pulley. *H* represents the pulley-shaft to the crushers. These pits, boiler and engine, etc., can all be covered by a shed, 30 × 50 ft. Where parties do not use the elevator, it is found desirable to make the pits, instead of 12 ft. wide and 20 ft. long, 20 ft. wide and 12 ft. long. In this case the machine is placed in the center of each pit, and moved from one to the other. This is to facilitate getting clay to the machine, as in no case will the clay be at a greater distance than 12 ft. from the machine.

Drying Bricks.—Fig. 10 represents Chambers Bro. & Co.'s artificial drier. This drier consists of six or more brick flues, about 40 ft. long, 3½ ft. wide, and 4 ft. high, built of bricks, with a railroad track through each, slightly descending from the machine, with fire-grates and doors at the lower end and a stack at the upper end. From the grates, upon which coal, coke, or wood is burned, the results of combustion are conveyed along in a flue under the bottom of the track to near the stack end, and are allowed to escape therefrom gradually, through perforations or slots, up, under, through, and between the bricks on the iron cars. For each tunnel there are two chambers for the admission of air, one on either side of the grate compartment, which enter the conveying-flue just back of the grate surface. In addition to the gases from combustion, a large amount of air is admitted over and at the sides of the furnace into the flue, which becomes heated, and, when distributed through the bricks by the adjustable flue, takes up the moisture from the bricks and carries it off through the stack. The proportion of air to the results of combustion is regulated by swinging dampers, while the draft of the fire is under independent control by the ash-pit doors.

The bodies of the cars used with this drier are made of wrought channel-iron, a rigid open framework, on which the pallets are piled. A boy can transport 504 bricks on one of them.

The "pallets" consist of two strips of wrought channel-iron secured at either end to a handle whose height is greater than the width of the brick. These handles are so constructed

that when the pallets are piled one on top of the other, they are securely interlocked. At each end of the flues is a transfer or switching car, which transfers the loaded cars from a single track, running from the machine, on to any one of the six running into the flues; and in like manner from any one of the six flues to the track running to the kilns. The loaded cars are transferred into any one of the kilns by means of transfer-cars, and the empty ones returned to the machine by a return track, outside of the flues. Each car, with its load of

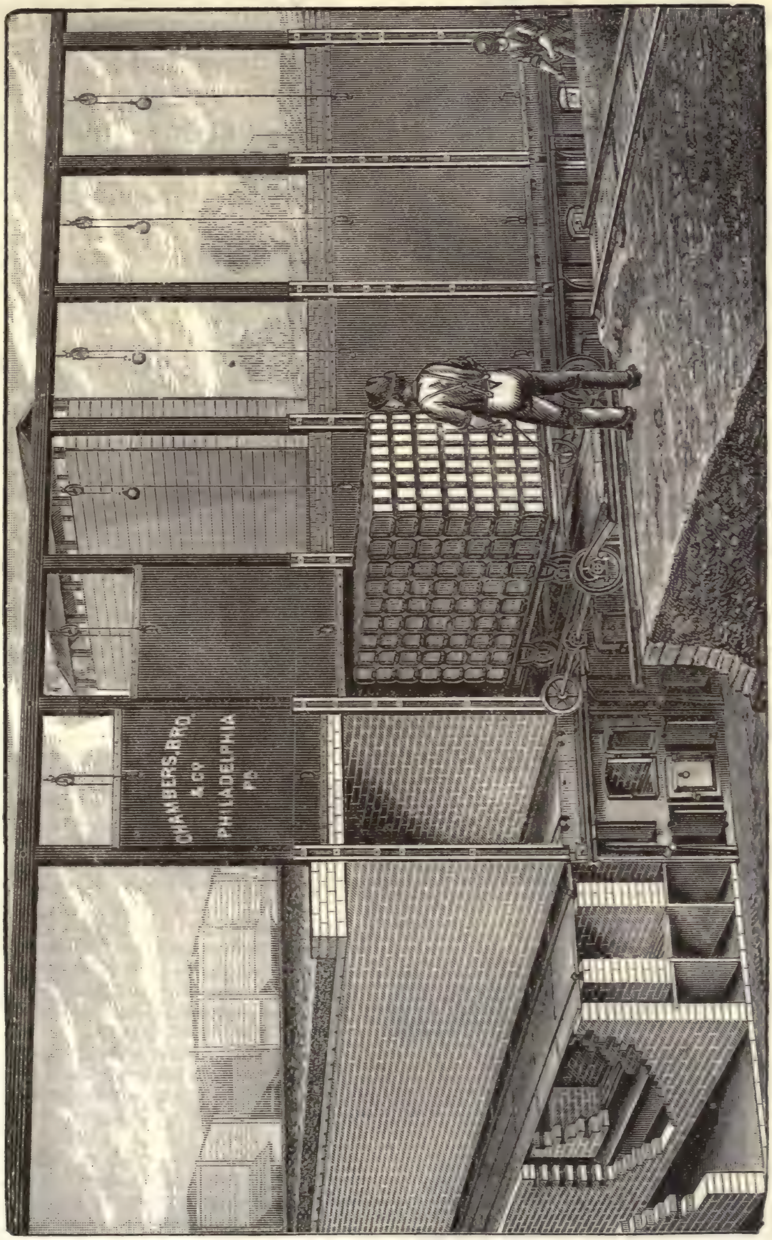


FIG. 10.—The Chambers brick-dryer.

sixty-three pallets, is brought to the side of the brick-machine. One man transfers the empty pallets from the car to the "pallet-carrier," which carries them along parallel with the off-bearing belt, and close to it, at a convenient speed, to enable the "off-bearers" to hack the bricks upon the pallets. The motion of the pallet-carrier is continuous, and when a pallet has received its quota of eight bricks it reaches a point opposite an empty drying-car. Here one or more men, as the capacity of the machine may require, lift the loaded pallets from the carrier to the car. When the car is full it is ready to be drawn to the drier, and another that

has just been emptied takes its place. The loaded car is then run on to the transfer-car, and thence into any one of the flues, where a current of heated air (an artificial summer breeze) is

Fig. 11.—Brick-truck.

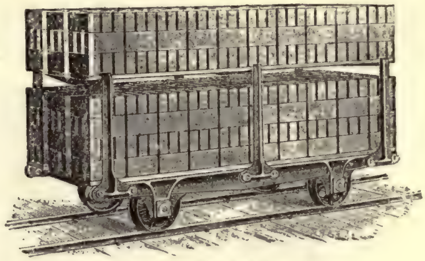


Fig. 12.—Dry brick-car.

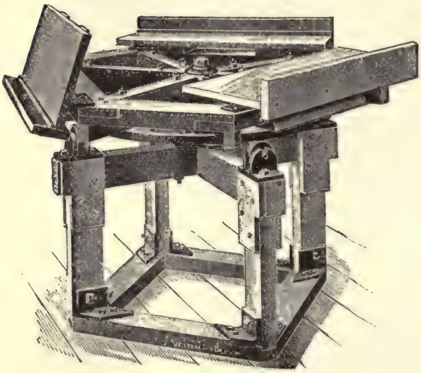


Fig. 13.—Dump-table.

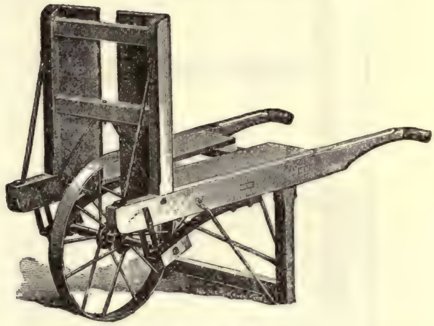


Fig. 14.—Brick-barrow.

forced through them, the steam from the bricks near the fire condensing on the surfaces of the cold ones and preventing checking or cracking, while the bricks absorb the heat from the steam and commence drying from the inside first. When the bricks directly over the fire are dry, the car is run out to the kiln to be set, a fresh car being put in at the upper end, pushing the others down and bringing another partially dry car immediately over the fire, and so on. It is claimed that one ton of anthracite coal will thus dry 25,000 bricks; hence the expense of artificial drying is less than that of sunshine.

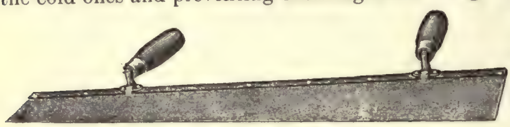


Fig. 15.—Strike-knife.

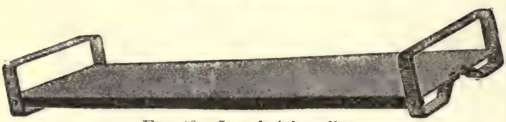


Fig. 16.—Iron brick-pallet.

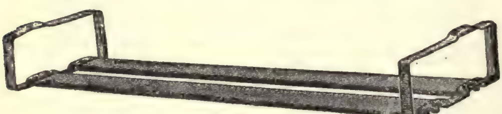


Fig. 17.—Steel brick-pallet.

Figs. 11 to 17 represent a variety of improved brick-yard appliances. Fig. 11 is a platform spring-truck suitable for handling green bricks when placed upon pallets. Fig. 12 is a double-decked dry car, on which the bricks are hacked four courses high on the lower deck and three courses high on the upper deck. Fig. 13 is a revolving dump-table. Fig. 14 is a barrow designed for wheeling green or burned bricks. Fig. 15 is a brickmaker's strike-knife. Fig. 16 is a wrought-iron interlocking pallet for stiff-tempered bricks; and Fig. 17 is a steel pallet for bricks molded on flat side, or for those stiff enough to stand on edge.

Broach, Channeling: see Quarrying Machinery.

BROACHING-MACHINES. *Nicholson & Waterman's Broaching-Machine.*—Figs. 1, and 2 show a broaching-machine built by Nicholson & Waterman, Providence, R. I., arranged for milling the sides of nuts and bolt-heads. The cutters consist of straight mills, with teeth set angling and slightly hooking. Two sides are finished at one pass. The cutters are set in a swivel-head, and approach each other at the bottom. The head swings from under the plunger to facilitate the entering of work. Guide or holder blocks secure the uniformity of angle, centralization of bolt-head or nut, and serve as a gauge for uniform size. The action of the plunger is automatic in its return. A rotary pump feeds lubricant upon the work from a tank placed under the working top. The principle upon which the cutting is done is that of a shaving or drawing cut. The nut or bolt is forced down between the mills, and is guided centrally. The time occupied in milling two sides is about four seconds; for

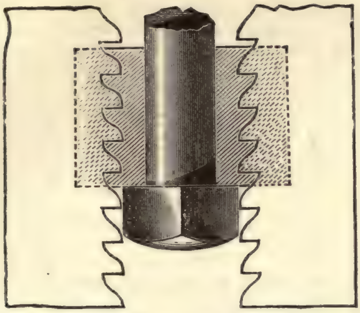


FIG. 1.—Broaching-cutters

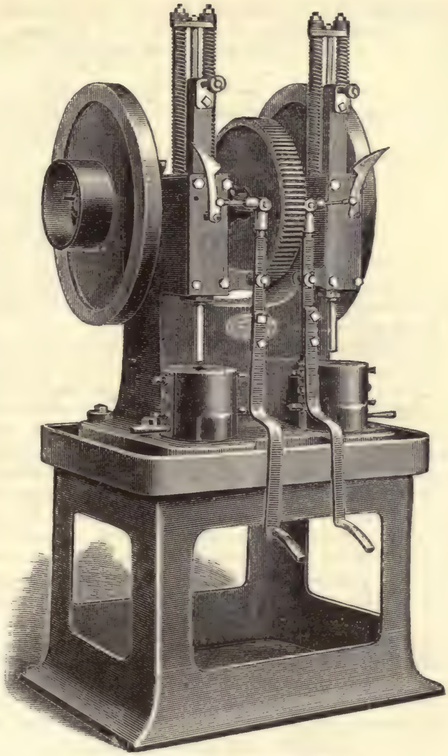


FIG. 2.—Broaching-machine.

the six sides, twelve seconds. The remainder of the time is taken in handling the work, the conveniences at hand and the dexterity of the operator having much to do with the product. As high results have been obtained as two finished hexagonal bolt-heads per minute. Under the worst conditions, it is claimed that a product of 500 hexagonal nuts per each ten hours can be obtained. For bolt-heads the product is considerably more, as the time in screwing a nut on to its pin (in order to mill centrally with the thread) is saved. A broaching-machine made by The Pratt & Whitney Co., Hartford, Conn., is designed for broaching holes of such diametrical form that they can not be finished by rotary motion, as drilling or reaming. It will work cavities up to $2\frac{1}{2}$ in. diameter. It is adapted also for drawing or for finishing the outside of work.

Bronze: see Alloys.

Bucket, Dredging: see Dredgers and Excavators.

Buddle: see Ore-Dressing Machines.

Burglar-Proof Construction: see Safes and Vaults.

CALORIMETER. An instrument for measuring quantity of heat. In steam-engineering the term is usually applied to an apparatus for determining the heat in steam and the percentage of its contained water.

The Barrel Calorimeter.—The simplest form of calorimeter for determining the quality of steam is a barrel containing about 300 lbs. of water set on a platform scale. About 10 lbs. of the steam whose quality is to be determined is carried into the barrel through a hose and condensed. From the observed data of temperatures, pressure, and weights the calculation of the quality of steam is made as follows, according to the formulæ proposed by Charles E. Emery (*Trans. A. S. M. E.*, vol. vi, p. 291):

Let W = original weight of water in calorimeter.

Let w = weight of water added by heating with steam.

Let T = total heat in water due to the temperature of steam at observed pressure.

Let H = total heat of steam at observed pressure.

Let l = latent heat of steam at observed pressure = $(H - T)$.

Let t = total heat of water corresponding to initial temperature of water in calorimeter.

Let t' = total heat in water corresponding to final temperature of water in calorimeter.

Let Q = quality of steam.

Then

$$Q = \frac{1}{l}\left(\frac{W}{w}(t' - t) - (T - t')\right). \tag{1}$$

Then when $Q < 1$, percentage of moisture in steam $= 100\ (1 - Q)$.

When $Q > 1$, number of degrees steam is superheated $= 2{\cdot}0833\ l\ (Q - 1)$.

The later practice of the writer, when there are a large number of calculations to be made, is as follows:

Add to above notation the following:

Let m = percentage of moisture in steam.

Let s = number of degrees steam is superheated.

Let A = number of heat-units lacking per pound of steam condensed. Equals quantity in parenthesis, equation (2).

Let Σ = sign of summation. To be read: Sum of values of—

Let n = number of experiments to be averaged.

Then

$$\text{(2)}\qquad m = \frac{1}{l}\overbrace{\left((H - t') - \frac{W}{w}(t' - t)\right)}^{A}.$$

$$\text{(3)}\qquad Q = 1 - m.$$

When A or m is minus.

$$\text{(4)}\qquad s = -2{\cdot}0833\,A.$$

Averaging several experiments.

$$\text{(5)}\qquad m = \frac{\Sigma A}{n\,l}.$$

$$\text{(6)}\qquad s = -2{\cdot}0833\,\frac{\Sigma A}{n}.$$

In the use of the barrel calorimeter the weight of the water, before and after condensing the steam, requires to be determined with accuracy. An error of ¼ lb. will cause an error of 3 per cent in the result.

Coil Calorimeter.—The following is a description of a calorimeter designed by William Kent, in which some of the probable errors of the ordinary barrel calorimeter are lessened:

A surface condenser is made of light-weight copper tubing, ¾ in. in diameter and about 50 ft. in length, coiled into two coils, one inside of the other, the outer coil 14 in. and the inner 10 in. in diameter, both coils being 15 in. high. The lower ends of the coil are connected by means of a brazed T-coupling to a shorter coil, about 5 in. long, of 2-in. copper tubing, which is placed at the bottom of the smaller coil, and acts as a receiver to contain the condensed water. The larger coil is brazed to a ¾-in. pipe, which passes upward alongside of the outer coil to just above the level of the top of the coil and ends in a globe-valve, and a short elbow-pipe which points outward from the coil. The upper ends of the two ¾-in. coils are brazed together into a T, and connected thereby to a ¾-in. vertical pipe provided with a globe-valve, immediately above which is placed a three-way cock, and above that a brass union ground steam-tight. The upper portion of the union is connected to the steam-hose, which latter is thoroughly felted down to the union. The three-way cock has a piece of pipe a few inches long attached to its middle outlet and pointing outward from the coil. A water-barrel, large enough to receive the coil and with some space to spare, is lined with a cylindrical vessel of galvanized iron. The space between the iron and the wood of the barrel is filled with hair-felt. The iron lining is made to return over the edge of the barrel, and is nailed down to the outer edge so as to keep the felt always dry. The barrel is furnished also with a small propeller, the shaft of which runs inside of the inner coil when the latter is placed in the barrel. The barrel is hung on trunnions by a bail by which it may be raised for weighing on a steelyard supported on a tripod and lifting lever. The steelyard for weighing the barrel is graduated to tenths of a pound, and a smaller steelyard is used for weighing the coil, which is graduated to hundredths of a pound. In operation the coil, thoroughly dry inside and out, is carefully weighed on the small steelyard. It is then placed in the barrel, which is filled with cold water up to the level of the top of the globe-valves of the coil and just below the level of the three-way cock, the propeller being inserted and its handle connected. The barrel and its contents are carefully weighed on the large steelyard; the steam-hose is connected by means of its union with the coil, and the three-way cock turned so as to let the steam flow through it into the outer air, by which means the hose is thoroughly heated; but no steam is allowed to go into the coil. The water in the barrel is now rapidly stirred in reverse directions by the propeller and its temperature taken. The three-way cock is then quickly turned, so as to stop the steam escaping into the air and to turn it into the coil; the thermometer is held in the barrel, and the water stirred until the thermometer indicates from five to ten degrees less than the maximum temperature desired. The globe-valve leading to the coil is then rapidly and tightly closed, the three-way cock turned to let the steam in the hose escape into the air, and the steam entering the hose shut off. During this time the water is being stirred, and the observer carefully notes the thermometer until the maximum temperature is reached, which is recorded as the final temperature of the condensing water. The union is then disconnected and the barrel and coil weighed together on the large steelyard; the coil is then withdrawn from the barrel and hung up to dry thoroughly on the outside. When dry it is weighed on the small scales. If the temperature of the water in the barrel is raised to 110° or 120°, the coil will dry to constant weight in a few minutes. After the weight is taken, both globe-valves to the coil are opened, the steam-hose connected, and all of the condensed water blown out of the coil, and steam allowed to blow through the coil freely for a few seconds at full pressure. When the coil cools it may be weighed again, and is then ready for another test. If both steelyards were perfectly accurate, and there were no losses by leakage or evaporation, the difference between the original and final weights of the barrel and contents should be exactly the same as the difference between the original and final weights of the coil. In practice this is rarely found to be the case, since there is a slight possible error in each weighing, which is larger in the weighing on the large steelyard. In making calculations the weights of the coil on the small steelyard should be used, the weights on the large steelyard being used merely as a check against large errors. It is evident that this calorimeter may be used continuously, if desired, instead of intermittently. In this case a continuous flow of condensing water into and out of the barrel must be established, and the temperature of inflow and outflow and of the condensed steam read at short intervals of time.

The Barrus Universal Steam Calorimeter.—This instrument was devised by George H.

Barrus in 1889. It is fully described in the *Trans. A. S. M. E.*, volume xi, and the following account is taken from that publication. The current of steam to be tested is first passed through a chamber in which the free moisture is deposited and measured, and subsequently it is carried through an orifice and discharged to the atmosphere, by means of which the partially dried steam is wiredrawn and superheated, and its exact final condition determined. The apparatus is shown in the following cut:

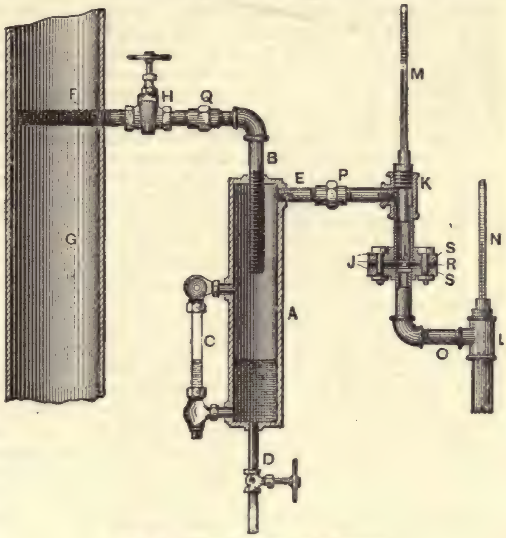


FIG. 1.—The Barrus calorimeter.

The principal parts consist of the chamber *A*, or "drip-box," and the wiredrawing apparatus or "heat-gauge," consisting of the orifice *I*, and the two thermometers *M* and *N*. The instrument is connected to the main steam-pipe *G*, which carries the steam to be tested by means of the perforated pipe *F*, and this pipe extends across the full diameter, in order to obtain a sample of the steam tested. The orifice *I* opens into a pipe which is in free communication with the atmosphere. By the use of the orifice a continuous current of steam is made to pass through the whole apparatus, and the current has a constant rate so long as the pressure is constant. The amount of moisture which the heat-gauge alone will measure varies somewhat according to the pressure. If the pressure is 80 lbs., it will measure between 3 per cent and 4 per cent. It is unnecessary to use the drip-box unless the quantity of moisture is in excess of, say, 3 per cent. The unions *P* and *Q* are therefore made interchangeable. When a test is to be made, the heat-gauge is first applied directly to the union *Q* and a preliminary trial made, to see what the general condition of the steam is. Whenever the moisture exceeds 3 per cent, or the limiting quantity at the existing pressure, the thermometer *N* shows a temperature of about 213°, and drops of water will generally be seen escaping from the open discharge-pipe. If the quantity of moisture is not beyond the range of the wire-drawing instrument, the temperature shown by thermometer *N* will be in excess of 213°.

In using the complete apparatus, the condensed water from the drip-box is drawn off by means of the valve *D* into a bucket resting on scales, and the quantity drawn off is regulated so as to keep the water-level, as shown in the glass *C*, at a constant point. When the quantity of moisture drawn off from the drain-valve *D* has been determined for a given time, the percentage of moisture which this represents must be found by comparing it with the total amount of steam passing through the apparatus. The trial may be determined either by computation or by trial. The computation may be made by finding the exact area of the orifice, and computing the quantity which passes through by means of the formula,

$$Q = \frac{\text{Pressure above zero} \times \text{area}}{70},$$

which gives the number of lbs. discharged through the orifice per second. The pressure to be used is that corresponding to the temperature shown by thermometer *M*. The quantity, as thus found, is accurate enough for rough comparisons. The exact quantity can be determined by conducting the steam discharged from the open end of the apparatus into a tub of water placed on scales, or, what is a better way, into a coil of lead pipe, or iron pipe, surrounded by flowing water, in the manner of a surface condenser, and weighing the condensed water drawn off in a given time.

A certain amount of moisture is produced by radiation from the apparatus itself, even though all the parts are well covered, as it is quite necessary that they should be, with hair felting. The readings of the instrument on the test must therefore be corrected for the loss thus occasioned. It has been the practice of the author to make these corrections by observing the indications when the apparatus is supplied with steam from the pipe *G* at a time when the pressure is steady and the pipe contains nothing but dead steam, there being no current. This condition of things can generally be obtained in a factory at noontime, when the engine is stopped, or at night, after the close of the day's work. It may fairly be presumed that the apparatus is then supplied with dry steam, and whatever moisture collects in the drip-box *A*, and whatever difference is shown by thermometers *M* and *N*, is due simply to the loss of heat from radiation. When the loss from radiation has been thus obtained, the quantity representing that due to the drip-box is simply subtracted from the weight of water drawn off during the same length of time on the main test. The way in which the correction is applied to the readings of thermometers *M* and *N* is to take the reading of thermometer *N* on the radiation test when thermometer *M* indicates an average, and use this reading as a starting-point. The indication of thermometer *N* on the main test is then simply subtracted from this normal reading.

In order to compute the amount of moisture from the loss of temperature shown by the heat-gauge, the number of degrees of cooling of the lower thermometer N is divided by a certain coefficient, representing the number of degrees of cooling due to 1 per cent of moisture. This coefficient depends upon the specific heat of superheated steam, which, according to Regnault's experiments, is 0·48. In other words, the heat represented by 1° of superheating is 0·48 of a thermal unit. The author's experiments show that this quantity can not be applied exactly to the form of instrument under consideration. The quantity to be used varies somewhat according to the degree of moisture. For an instrument working under a temperature of 314° by the upper thermometer, and with a cooling by the lower thermometer from 268° to 241°, the quantity was found to be about 0·42. When the cooling, however, was from 266° to 225°, the quantity to be used was found to be about 0·51.

The experiments have not as yet covered a sufficient range to determine the exact law which can be applied to every case, but it seems probable that the specific heat is more or less constant until the temperature by the lower thermometer approaches the point of saturation for the low-pressure steam, while beyond this point the specific heat rapidly increases. For the present, it is assumed that the quantity 0·42 is the proper one to apply whenever the temperature by the lower thermometer is above 235°, and that in cases where the temperature is below 235° the quantity is to be used as an increasing one, reaching perhaps to 0·55 when the temperature drops to 220°.

One per cent of moisture, now, represents the quantity of heat determined by multiplying the latent heat of 1 lb. of steam, having a pressure corresponding to the indication of thermometer M, by 0·01, and this product is to be divided by 0·42 (provided the lower temperature is not below 235°), in order to express it in terms of degrees of superheating. For example: When thermometer M shows 312°, the latent heat is 8·94 thermal units, and 1 per cent of this is 8·94; dividing by 0·42, the number of degrees of superheat corresponding to 1 per cent of moisture is found to be 21·3. For several other temperatures, which cover the ordinary range that would commonly be used, the necessary coefficient is given in the following table:

Temperature by thermometer M.	Coefficient.	Temperature by thermometer M.	Coefficient.	Temperature by thermometer M.	Coefficient.
270°	22	310°	21·3	350°	20·6
280°	21·8	320°	21·1	360°	20·5
290°	21·7	330°	21		
300°	21·5	340°	20·8		

Canal Lift: see Elevators.

Cannon: see Ordnance.

Car-Brake: see Brakes. **Car-Brass Grinder**: see Grinding Machines. **Cars, Railroad**: see Railroad Cars. **Car-Wheel Lathe**: see Lathes, Metal-Working.

Card: see Cotton-Spinning Machinery.

CAR-HEATING. Car-heating, in the general acceptance of the term, has come to mean the heating of railway-cars by the use of steam from the locomotive. It is also technically described as continuous heating.

The Commingler System of the Consolidated Car-Heating Co., of Albany, N. Y., depends upon the direct action of the steam upon the water of circulation, caused by the steam discharging within the body of the water itself. The contact of the steam and water takes place within the pear-shaped body of the commingler proper, a sectional view of which is shown in Fig. 1. The flow of steam is broken into hundreds of small jets within a body of quartz pebbles in such a manner as to silently force the water through the commingler after imparting to it the entire heat of the steam. By giving the proper form and direction to the steam-jets within the commingler, a forced as well as a gravity circulation is readily obtained, and it is the addition of this feature of forced circulation which enables the commingler to move the water through such large circuits. Any amount and distribution of piping that may be found desirable can therefore be made in a car, the capacity of the commingler being fully assured. With the commingler the heating system is kept constantly filled from the condensation which takes place within the commingler, and thus water in the expansion-drum is always level with the top of the overflow-pipe. Five lbs. steam-pressure in the train-pipe at the car is claimed to be sufficient to heat the largest car in the coldest weather. Experiments conducted under the supervision of the New York Central Railroad showed that circulation was rapidly established by the commingler with 1¾ lbs. of steam.

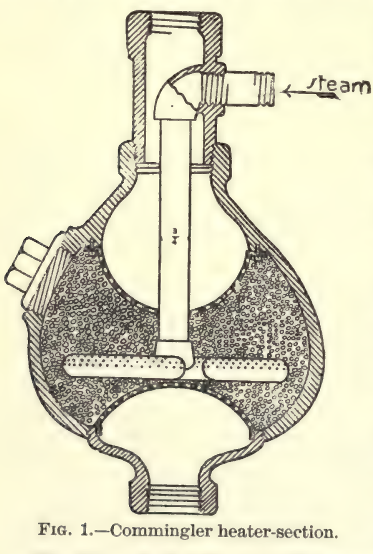


FIG. 1.—Commingler heater-section.

The Commingler Storage System.—A small commingler, as shown in the cut, is placed under the middle seats on each side of the car, between the floor of the car and the sheathing.

The outflow connection of this commingler is connected with one end of the side piping, and the other end, forming the return, is connected with a valve, and thence into the base of the commingler. A complete circuit is thus established, through which a continuous flow of water may take place. The overflow, through which surplus water is removed from the system, is connected with the fitting, which is placed at the highest point in the system. When the pipes are entirely filled, the surplus water flows from this fitting through the restricted opening in the trap-cock, and thence down through the channel-way, cast in the base of the commingler, and out at the drip-pipe. The connection of the overflow-pipe to the base of the commingler is made to prevent possibility of freezing of the drip-pipe in cold weather. This danger is provided against by connecting the steam-pipe into ports in the same casting, so that the base of the commingler is warmed even when steam is shut off of the apparatus within the car. The course of the steam can be traced from the nipple connecting into the base. When the pipes are filled with water of condensation, a complete circulation automatically takes place every seven minutes, and all surplus is carried off through the overflow-pipe. When the car is laid off for the night or for more than three or four hours, the entire system is quickly emptied of water, and the car is then ready to stand out in any temperature, however cold, without danger of any part of the apparatus freezing, and it is also ready to be quickly heated by direct steam when again brought into use.

Drum Systems.—Several forms of car-heating apparatus have been introduced more or less extensively, which, as a class, are known as drum systems. This method of heating employs a hot-water circulation within the car, to which a "Baker" or other similar heater is attached. To provide a means for maintaining heat in the car when steam from the locomotive is used, a drum is employed to transfer the heat of the steam to the water of circulation.

The Coil-Drum.—The drum generally consists of a pipe of 6 in. in diameter and about 4 ft. long, and capped at both ends. In this drum is placed a coil of copper pipe, which coil is made a part of the hot-water circuit within the car. Steam from the locomotive is admitted to this drum around the copper coil, through which heat is imparted to the water of circulation. That part of the circuit above this drum becoming relatively lighter than the descending column of the hot-water circuit, a movement of the circulating medium is produced, creating a steady flow up through the coil. It is evident that the amount of heat communicated to the circulating medium depends upon the surface of the coil and upon its conductive power to heat. In order to maintain the water of circulation at or near its boiling-point, a pressure of from 10 to 20 lbs. of steam must be carried in the drum. The Sewall drum-system is, perhaps, the most widely used of this type of heater. This drum is placed within the car by the side of the heater, and is connected with the circulating pipes so as to form a branch circuit around the heater. At the point where the two circuits unite above the drum is placed what is known as a current-director, which is a casting so arranged that the force of the moving circuit from the drum creates an upward flow through the heater, so as

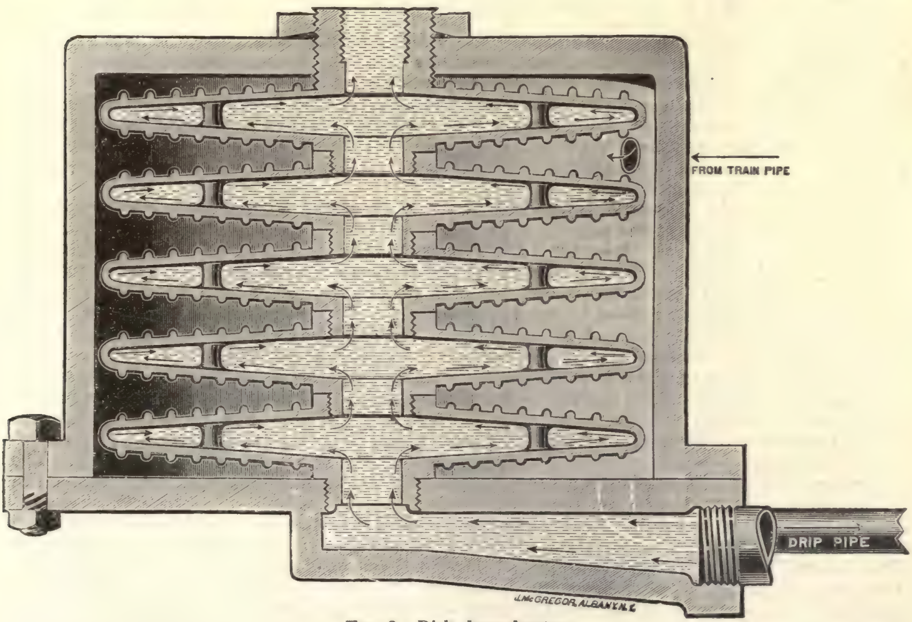


Fig. 2.—Disk drum-heater.

to produce a circulation through the piping in the car. In case this current-director is not used, the drum is apt to produce a short circuit, creating a downward flow through the coil of the heater.

Salt-water usually constitutes the circulating medium in this system, which water has a freezing-point of abont 10° above zero. When solutions of salt, giving a lower freezing-point, are used, the excess of salt is liable to deposit in the circuit within the coils of the drum and the heater, and so to greatly reduce the effectiveness of the heating apparatus.

The Disk-Drum System is a modification of the coil-drum above described. A series of bronze castings made in the form of hollow disks take the place of the coil within the drum. The disks are 12 in. in diameter, and are securely screwed together at their centers. Eight strong studs are cast midway between the center and the circumference of each disk, for the purpose of binding its walls together. These studs are necessary to give sufficient strength to withstand the enormous pressure liable to come upon the circulating pipes when fire is used in the heater. All disks are tested at 500 lbs. per sq. in. Five disks are usually employed in each drum, although seven disks are sometimes used. Each disk is ribbed or corrugated, and has 2 sq ft. of heating surface, so that the heating surface in each drum varies from 10 to 14 sq. ft., depending upon the number of disks employed. This construction allows a large amount of heating surface to be put into a compact form, and also presents a very small internal resistance to the flow of water through the disks. The drum itself is made of cast iron, to which a cast-iron head is bolted.

Two drums thus constructed are connected with the heating circuit of each car at its lowest point (see Figs. 2 and 3). They are placed so as to form the risers from the cross-over pipes,

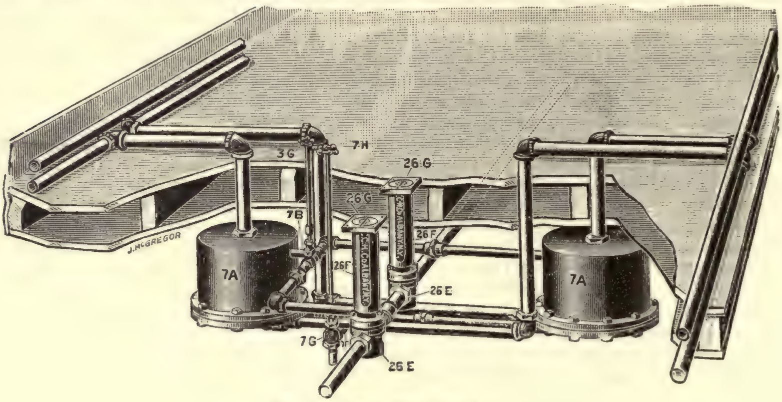


Fig. 3.—Disk drum-heater.

and as the two drums discharge into the pipes on different sides of the car, the heat in the car is evenly distributed It is evident that the joint action of the two drums is to produce the circulation of water in the same direction through the pipes. The direction of flow is the same as when fire is used in the heater. Since the water is heated at two points, all the water is heated when it has moved through one half of a complete circuit. Steam is taken into the drum from the train-pipe, and water of condensation is removed from the drums by means of a trap or trap-valve and is discharged on the ground. A brine of salt and water is generally used as the circulating medium.

The Direct-Steam System.—In this system steam from the locomotive is turned directly into the radiating pipes of the car. Three pipes $1\frac{1}{4}$ in. in diameter are generally used on each side of the car. The three pipes are joined together at both ends of the car by a three-pipe manifold. A distributing tee is placed near the center of the car, and is connected into the two upper pipes. To this distributing tee a pipe leading from the train-pipe is connected, through which steam is supplied to the heating pipes. A tee is also placed in the lower pipe near the center of the car, and a drip-pipe is connected from this tee to a casting placed in the train-pipe in which is a bleeder-valve controlling the discharge to the ground. The pipes in the car are graded so that water will flow to the ends of the car in the two upper pipes, and then flow to the center of the car in the lower pipe, and out through the drain-pipe and the bleeder-valve in the train-pipe casting, to the ground. In the same train-pipe casting is placed the steam-valve which controls the flow of steam to both sides of the car, and the drip-pipes from both sides of the car are also controlled by the one valve above described. The two valves in the train-pipe casting are provided with extended spindles, which terminate in a floor-plate made flush with the level of the floor.

The office of the train-pipe casting above mentioned is to prevent the drip-pipes from the car from freezing by connecting them into a casting always deriving heat from the train-pipe. This feature, patented by the Consolidated Car-Heating Co., is one of great importance as, by removing the possibility of freezing the drain-pipe when the bleeder-valve is closed, it becomes practicable to nearly close the bleeder-valve and allow the pipes to fill with water of condensation when but little heat is required. In this way the fierce heat of direct steam can be toned down to meet the requirements of mild weather. In cold weather the bleeder-valve is given a larger opening, so as to allow the greater part of the radiating pipes to be filled with steam. This construction furnishes an effective means of adjusting the amount of piping filled with steam to the needs of all kinds of weather.

Temperature Regulators.—Automatic devices designed to regulate the temperature of the circulating medium in heating apparatus have been used for several years. These devices, however, have not been wholly successful in regulating the temperature of rooms, because they have been actuated by the return water to the heating apparatus, and have been designed to close the damper when the temperature of the return water reached a certain point. As it is desired in heating cars that the return should be, in cold weather, at a much higher temperature than in moderate weather, it is evident that the temperature of the return affords no indication of the temperature of the car. Suffice it to say that for car-heating purposes especially, the temperature of the car and not the temperature of the heating, pipes must govern in automatic devices.

Of recent years several devices have been introduced that have gone a step further, and have been so arranged that they are actuated by the temperature of the car itself. In the line of improvement here indicated, the Johnson regulator has been introduced to a limited extent. This is a device in which a thermostat is used to make electrical contacts; one contact when the temperature of the car reaches 72° and an opposite contact when the temperature reaches 70°. The electrical contact made at 72° closes the circuit of the battery so as to actuate an electro-pneumatic valve, which admits air under pressure from the auxiliary reservoir of the air-brake apparatus to a pneumatic steam-valve. This is an ordinary form of steam-valve in which the valve-stem is connected to a diaphragm by means of which the valve is closed by the air pressure above referred to. When the temperature of the car reaches 72°, provided the apparatus has been set for that temperature, the steam is automatically shut off from the car. When the temperature falls to 70°, an opposite contact is made which, operating the electro-pneumatic valve in the opposite direction, the air-supply from the auxiliar reservoir is shut off, and the diaphragm of the pneumatic steam-valve is allowed to open, and steam is again admitted to the car.

The Consolidated Car-Heating Co.'s Regulator is a graduated apparatus, and is so arranged that the steam-valve at all temperatures below 60° stands wide open. At 60° the valve begins to close, and gradually approaches its seat until the temperature of the car reaches 74°, when

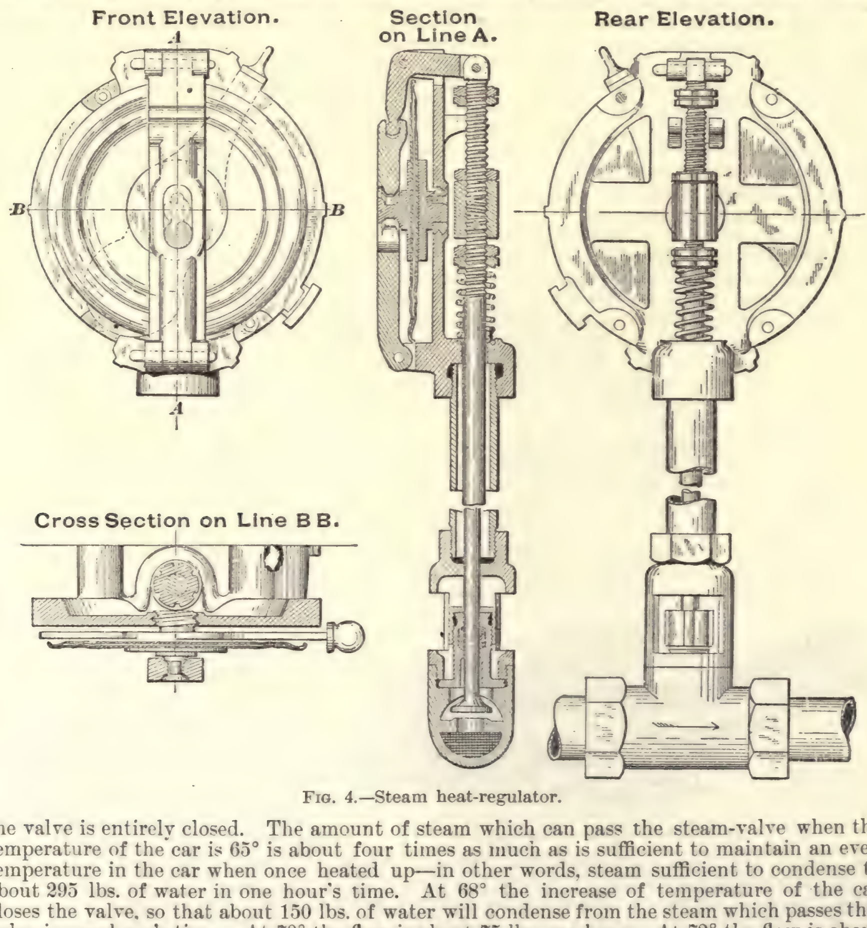


FIG. 4.—Steam heat-regulator.

the valve is entirely closed. The amount of steam which can pass the steam-valve when the temperature of the car is 65° is about four times as much as is sufficient to maintain an even temperature in the car when once heated up—in other words, steam sufficient to condense to about 295 lbs. of water in one hour's time. At 68° the increase of temperature of the car closes the valve, so that about 150 lbs. of water will condense from the steam which passes this valve in one hour's time. At 70° the flow is about 75 lbs. per hour. At 72° the flow is about

20 lbs. per hour. At 74° to 75° the valve entirely shuts off. It is evident that the temperature of the car equipped with this apparatus would rise to that temperature at which just sufficient steam passes the steam-valve and into the car as is necessary to maintain an even temperature, and at no time is it necessary that the steam-valve should actually shut off. It gives a throttling action upon the flow of steam. Taking into consideration the rapid rate at which this valve closes, it will be seen that, under conditions of railway service, the temperature of the car would be kept practically constant. In actual practice it has been found that the temperature of the car will be kept at 70° and within a maximum variation of 2°.

The detailed construction of this apparatus can be seen from Fig. 4. Two metallic diaphragms are employed, which are brazed together at the edges, and have metallic hubs soldered to their opposite faces at their centers. (See section on line *A*.) A small quantity of a liquid whose boiling-point is 60° F. is placed within the space between the two diaphragms. The opening to this space is then hermetically sealed. The diaphragm is then attached into a bronze framework in such a manner that the expansion of the diaphragms is communicated by means of a lever to a bell-crank, which through a rod actuates the steam-valve below. This pipe is 5 ft. long and holds the two parts of this apparatus in rigid adjustment, and also offers a protection to the rod. At a temperature below 60° F. the liquid placed between the two diaphragms remains in the form of a liquid, and the two diaphragms are collapsed. Above the boiling-point of the liquid in these diaphragms a vapor pressure is generated between the two diaphragms, forcing them apart and causing a motion in the vertical rod and its connecting mechanism against the tension of the spring shown in the framework of the regulator. The steam-valve is caused to close partially by this same movement. When the temperature rises to 70° the valve almost reaches its seat, and simply allows sufficient steam to pass to preserve an even temperature in the car. If a ventilator is open or in any way the air in the car is chilled, the effect on the diaphragms is to lower their temperature and to cause them to collapse, which is followed by a corresponding opening movement in the steam-valve. The results of tests with this apparatus have shown that the temperature of a car can be automatically held within a maximum variation of 2° with an external temperature varying from 50° above zero to 6° above zero in a run of 300 miles.

Independent Water-Heaters usually consist of a suitable jacket made of heavy sheet-iron, forming a combustion-chamber, in which is placed a coil of 1¼-in. pipe about 14 ft. long. These parts are properly mounted upon a base carrying the grate, with fire-pot and ash-pit, forming a heater of well-known construction. The coil referred to is connected up as a part of a hot-water circulating system. The heat of the combustion-chamber is conducted through the metal of the coil to the water, by which it is distributed through the circulating pipes. While this heater has rendered service for years in car-heating, it nevertheless has been found that in train-wrecks it is liable to set the cars on fire. To overcome this objection several heaters have been designed in which the fire is so inclosed that there is but little danger of live coals being scattered in case of a wreck. In an improved heater of this type the outside shell is made of 18-in. wrought-iron tubing, and is over ¼ in. thick. Within this is the cast-iron lining, which is separated from the shell by a ¼-in. thickness of asbestos fire-felt. Within this lining is placed a closely wound coil of 1¼-in. pipe 26 ft. long. Between the coil and the lining is an annular-shaped smoke-chamber 2 in. thick, through which the hot gases from the fire pass to the smoke-pipe on all sides of the coil. The closely wound coil is filled with coal, the fire burning only at the base of the coil. A perforated malleable-iron head is bolted into the upper end of the shell, through which smoke passes before reaching the stove-pipe. In this head a sliding door covers securely the opening through which coal is fed to the interior of the coil. In case the heater should be upset in an accident, the fire can not escape at either end of the shell.

Steam-Couplers.—In continuous heating one of the most difficult problems has been to secure a connection which would couple the ends of the train-pipes together, and so make a practically continuous steam-pipe leading from the locomotive under all the cars. Rubber hose has now been generally adopted as a means for taking up the motion between cars, and to the end of such hose is attached the steam-coupler proper. This coupler must couple easily, uncouple automatically, be durable, be exactly alike in each half, and the interchangeability must not be affected by wear. Many types have been brought out, among them the McElroy, Martin, Gold, Gibbs, and Emerson, embodying some of the above-mentioned desirable features, but the tendency for two years past appears decidedly toward what is known as the Sewall pattern, many railroads in the United States and Canada having recently adopted it for steam-heated trains. The Sewall is a straight-port, abutting-face, and insulated steam-coupler. The cuts herewith show its simplicity of construction. The passage for steam is practically straight and unobstructed by strainers, springs, diaphragms, gasket-retainers, or acute angles. All its metallic parts are made of malleable or wrought iron or steel. On the coupler-head are placed a tooth and space in proper position (shown in accompanying cut, Fig. 5), to serve the double purpose of a guide for the interlocking devices when being coupled, and also to retain the coupler-heads in proper

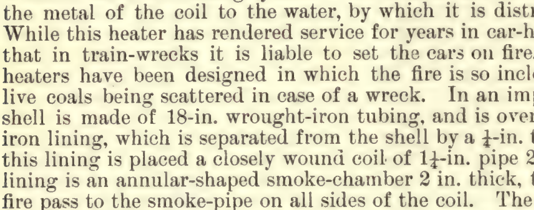


FIG. 5.—Sewall's steam-coupler.

relation while uncoupling. The locking features are constructed upon carefully calculated epicycloidal curves, thereby drawing the gaskets together in a direct line after contact. The center line of pressure exactly coincides with the center line through the locking devices, and hence gravity tightens the gasket faces. That the coupler is automatic in uncoupling is due to the curvature of the hose-nipple, the center line of draft being brought above the center line of pressure as soon as hose begins to approach a horizontal position. The gaskets are composed of peculiarly treated rubber and have sufficient elasticity as well as strength to form a perfect and durable steam-joint.

Carriage Drill: see Drills, Rock.

CARRIAGES AND WAGONS. *Buggies.*—A combination vehicle, having the appearance of the Brewster buggy, but said to excel it in riding qualities, is constructed with the Timken body cross-springs and the Brewster end-springs (see Fig. 1). The end-springs act as a

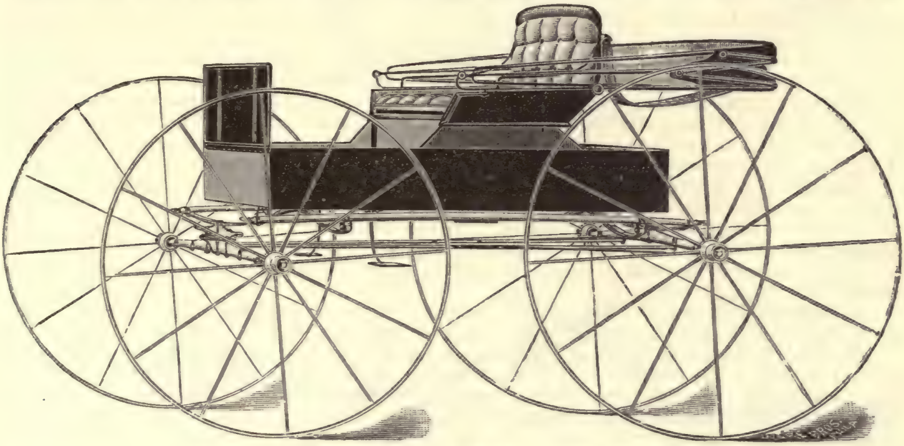


FIG. 1.—Buggy.

cushion when the buggy strikes any obstruction, and the long elastic cross-springs overcome the force of the jar, so that it will hardly be felt by the time it strikes the body; therefore, the occupants of the vehicle do not receive the same shock as they would in a vehicle where the force strikes the body direct from the wheels. A double-perch gear allows the perches to drop below the axle. The entire gear is illustrated in Fig. 2.

Dog-Carts.—Natural woods have the preference in this class. Among the improvements introduced in construction is an arrangement whereby, when the tail-board is moved down,

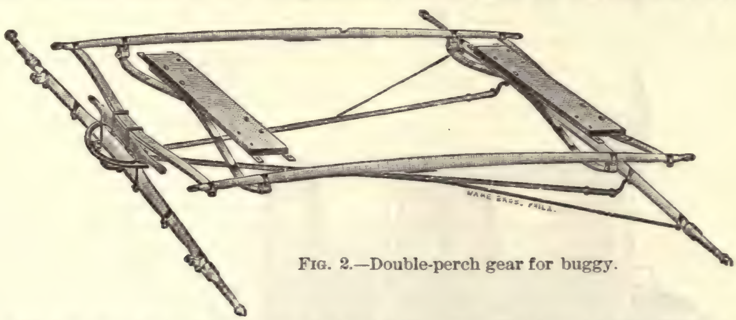


FIG. 2.—Double-perch gear for buggy.

the seat with the lazy-back slides forward about 6 in. The seat-board is hinged in the center, the rear side lazy-back being made to revolve so that the occupant can ride facing forward or backward. The whiffletree is connected with chains at the center and fastened to the axles at the springs.

The Wagonet is growing in favor for short-trip excursions, and designs are multiplying. In one of the latest productions the lines of the front gear are made to harmonize with the curves of the body, and greater firmness is given to the gear by distributing the weight evenly upon the fifth wheel. The king-bolt is placed ahead of the axle, without the usual curved bed. The dimensions are: Width of body on top, 42 in.; at bottom, 37 in.; distance center to center of axles, 63 in.; diameter of front wheels, 36 in., and rear, 45 in.; diameter of fifth wheel, 28 in. Track measured outside to outside on ground, 4 ft. 10½ in.

Buck-Boards are popular when finished in the natural woods. The rear seat is now frequently made reversible. A recent design has the front suspended upon one elliptic spring, while at the rear the bottom rests on the axle, and the rear seat is carried by an elliptic spring supported by the bottom over the axle.

A new and attractive design of buck-board, having three seats and a rumble (adapted for six passengers) meets with a steady demand. The natural-wood finish is again the favorite, with drab corduroy trimming and black iron-work. The construction of the body is simple. The bottom boards consist of three pieces of 1⅛-in. ash, with three cross-pieces 4 × 1⅛ in. in the center, tapered to ⅞ in. at the ends. At the rear end of the body two pieces are bolted to the bottom boards, extending back about 24 in. to take the foot-board for the rumble. The side-bars are of locust. There are front and rear springs, and a cross-spring both at front and rear, and the vehicle has two perches. Width of body, about 30 in.; wheels, 46 in. front and 50 in. rear in the wood; center to center of axles, 91 in.; track, 4 ft. 8 in.; diameter of half fifth wheel, 14 in. The above are the principal measurements only; builders of buck-boards will be able to readily supply the rest.

Another novelty in buck-board wagons was recently built in Newark, N. J. The front seat is hinged, and on lifting it a child's seat may be drawn out; this has a hinged iron support which then falls into place. The rear seat is hung on jump-seat or loop-irons, so that it may be placed in any part of the back of the body. The rumble is made of bent stock, as usual. As a nice set-off to the natural-wood body finish, the gearing is striped with carmine.

Light Spindle-Wagons.—The principal change in the designs of spindle-wagons is the slightly curved toe-bracket, which has a graceful and pleasing effect. The suspension is on cross Brewster springs, with side-bar and bolsters, which allow the body to be hung comparatively low. The body-sills are of hard body ash, bent at the toe to the shape of the pattern. A light rocker-plate screwed to the inside of the sills gives extra strength.

Surreys are now often made with four elliptic springs instead of suspending them on side-bars, or two elliptic springs with high wheels. A wheel-house can be used to great advantage in connection with this new arrangement. In one particular form the sides of the body are straight, and there is no door between the seats, but the front seat is made to turn over, which gives easy access to the rear of the body. Surreys also have canopied tops fitted to them occasionally.

Advertising Vehicles are constructed in a variety of styles, and their bodies often take the form of the goods carried, notably the shoe and the hat.

Hospital Ambulances.—One of the latest styles of ambulance-wagons has the body suspended, so that at the rear it is only 17 in. from the ground, which affords easy access to the interior from the rear, this being the desideratum. There is a wheel-house in front to allow of short turning. The upper part of the body is fitted with imitation shutters, which can be raised and lowered to admit of ventilation; these shutters are secured from rattling by light steel window-strips. The two doors at the rear are hung on concealed hinges, and open out practically the entire width of back. Two beds can be used in this wagon, one hung above the other. The front is suspended on an open futchel-gear, with the regular elliptic springs. The back has an axle cranked down 17 in., and is suspended on a half-double sweep-spring. The lower part of the body, up to where the spring is attached, is narrowed 3 in. on each side, being 48 in. wide outside at the top and 42 in. wide at the bottom, with a 5 ft. 2 in. track all round. The front wheels are 36 in. diameter and the rear 54 in.; number of spokes, 16; distance from center to center of axles, 78 in.; diameter of fifth wheel, 22 in.; weight of vehicle, complete, about 1,100 lbs.

The new French city ambulances, Fig. 3, constructed after the plans of Dr. Nachtel, of Paris, are models in their way. Its smooth and varnished sides permit the vehicle to be kept perfectly clean. A litter of light wicker-work, of proper and convenient form, gliding along two grooves, receives the patient, who, owing to the elasticity of this material, is enabled to rest comfortably, and without experiencing the usual though unnecessary jolting heretofore incidental to being rapidly conveyed over roughly paved streets. A little shelf contains all that is requisite for the dressing of wounds *en route*. The ambulance is lighted by two large windows on each side. The entrance at the rear is closed by means of full-width folding-doors, thus preventing the cold air and drafts from reaching the occupants, which is at present one of the objectionable features of the American ambulance.

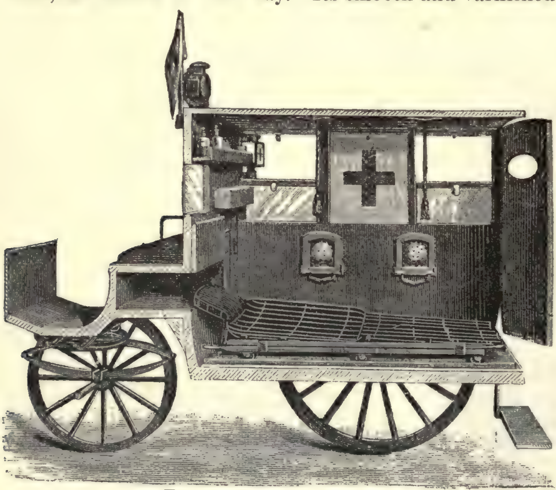


Fig. 3.—French ambulance.

Gears.—A new gear, known as the "Equivalent" (Bartholomew's patent), has been recently put upon the market. It is intended specially for "cut-under" vehicles, such as surreys, hacks, road-wagons, and light-delivery wagons, which are often required to turn short. This gear takes the place of the platform ordinarily used for carriages,

having a wheel-house under which the wheel runs in turning and "cramping," and in other styles of carriages, dispensing with the reach, which does not permit the wheel to turn completely under the wheel-house. A strong steel bar is bolted firmly to the under side of the front part of the body, and it extends rearwardly toward the wheel-house to a point just short of the path of the wheel, where it is curved downward (for from 6 to 12 in., according to the style of vehicle), forming a junction, through pivots, with two steel bars arranged one above the other (from 4 to 8 in. apart), with an intermediate tie or brace; these bars running forward and pivoted to a forged head-piece carried by the spring-bolster and fifth wheel, thus practically joining the front axle. This gear prevents rocking or horse-motion of the front spring, stiffens the connection between the axle and body, and insures perfect vertical motion in riding. The parts are generally made by drop-forging. A trussed wagon-gear of a late type, suitable for use with three springs, is shown in Fig. 4. It is known as the Selle patent, and finds much favor with carriage-builders for heavy work.

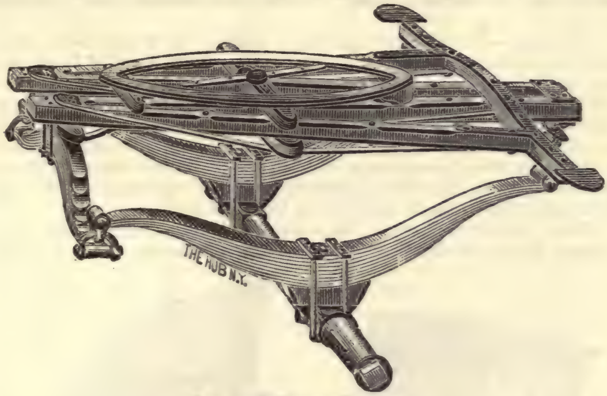


FIG. 4.—Selle carriage-gear.

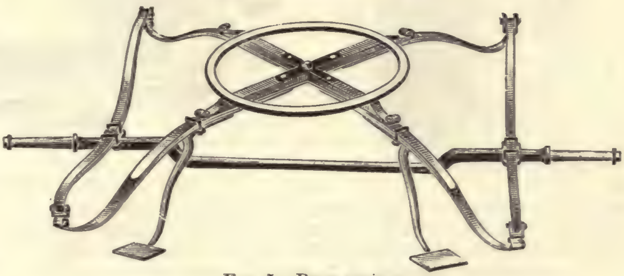


FIG. 5.—Rose spring.

The Rose patent combination platform-spring and gear has been used in various places during the last few years, and has been found especially valuable for light vehicles. The front axle is cranked down several inches so as to be crossed conveniently by two diagonally arranged spring-braces, which carry the fifth wheel at the point of their intersection. The ends of these cross-braces are joined to the ends of the side-springs, as shown in Fig. 5.

A new style cut-under Surrey body and gear, which makes a desirable easy-riding vehicle, is manufactured by the Mulholland Spring Co., of Dunkirk, N. J. The general construction and arrangement needs no description, the main point of difference from other gears being the bracing-bars running from the semi-elliptic front and rear springs to the body. The Anchor Buggy Co., of Cincinnati, has successfully applied a new principle in fifth wheels and attachments, both to double and single perch vehicles. The gear is known to the trade as the "patent anchor fifth wheel and king-bolt." Its chief features are a full-circle top and bottom wheel, with the king-bolt forming a part of five different attachments bolted together in rear of the axle by a double-head bolt, so that all wear can be taken up. Should any part break, this gear will not drop the body by the pulling apart of the front wheels and axle from the spring-bearing; but it is claimed that four breakages must occur before the body can drop sufficiently to endanger the occupant of the vehicle.

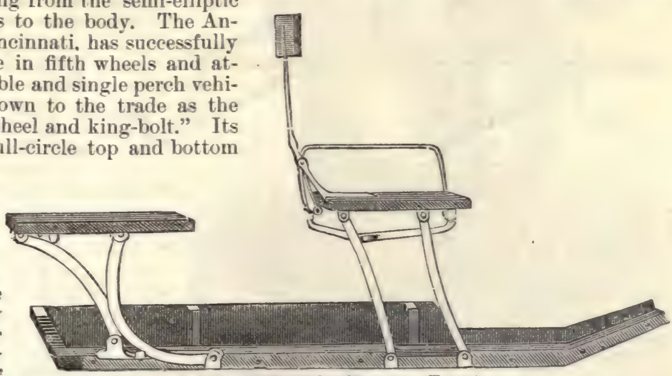


FIG. 6.—Lazy-back seats. T-cart.

Seats.—Fig. 6 shows a new arrangement of combination lazy-back locking jump-seat irons. Swinging rear seats for T-carts are now largely in vogue. They obviate the necessity of climbing over the rear wheels. A safety-seat for two-wheeled vehicles has a mechanical arrangement of rack and pinion and worm on the end of a hand-lever conveniently placed at

the right side of the driver, so that he can, quickly and easily, while retaining his seat and keeping both whip and reins in hand, glide the seat forward or backward to suit the inequalities of the road, and preserve the perfect balance of the carriage. Directly the handle is let go, or the driver ceases to turn it, the seat remains fixed and immovable. The arrangement can be attached to any existing two-wheeled cart; a sliding foot-rest usually accompanies it.

Springs.—Cushion-springs, when applied to a side-bar wagon, are capable of self-adjustment, so as to adapt themselves to any variation of load, and rendering the riding invariably easy, without reference to the number of persons occupying the vehicle. The inner ends of the steel cushions are fastened to the middle of the spring-bar with the same bolts as the steel springs, and the outer ends of the cushions are bolted to the side-sills. These cushions are only yielding to a slight degree—just enough to break the force of a sudden shock. They press down upon the springs, causing the openings between the cushions and springs to close, according to the amount of pressure, thereby virtually shortening the springs, and thus regulating their stiffness to agree with the load carried.

The Silvester Patent Tire.—Fig. 7 is practically a universal felloe-clamp. It has two vertical flanges which inclose the felloe, which effectually prevent it from coming off without

FIG. 7.—Silvester tire.

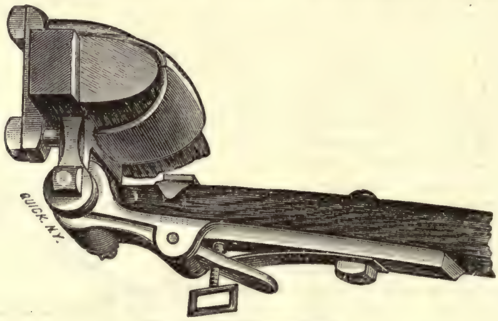


FIG. 8.—Thill-coupling.

requiring the use of screws, bolts, or other fastenings. To protect the felloe from damage by curb-stones, railway-tracks, etc., the tire has lateral rims or flanges, and the first-named flanges bind the felloe firmly together and prevent it from splitting.

The whole arrangement of flanges also strengthens both tire and felloe, and prevents bending or shrinking, thus effectually preventing the wheel from getting out of shape.

Thill-Couplings.—A novel form, made by the Instant Thill Coupling Co., is shown in Fig. 8. The clips upon the axle have forwardly projecting lugs coupled by a strong steel-bolt, which is embraced, in the space between the lugs, by a pair of semicircular jaws, one of the latter being rigidly attached to the shaft-end by bolts and clips, and the other pivotally connected with the first, leaving a thumb-lever projecting beyond the pivot so as to be easily pressed upon to open the jaws in shifting thills. There is a spring under it to regulate its play. No wrench is required, and absolute safety and the maximum convenience are claimed for the appliance.

FIG. 9.—Carriage-irons.

Carriage-Irons are largely duplicated by drop-forging, and these parts on all standard vehicles are consequently interchangeable throughout the respective styles and sizes. The accompanying cuts, Figs. 9 and 10, represent forged shifting rails of two different designs, as made by the Clapp Manufacturing Co., of Auburn, N. Y.

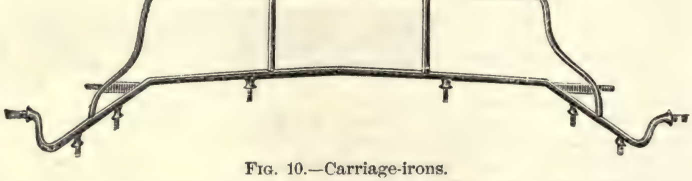


FIG. 10.—Carriage-irons.

Lighting. — An electric light has been successfully used in a wagon, employed by the Chief of the Boston Fire Department. Incandescent lamps with reflectors are placed in the lanterns on either side of the seat, and these are supplied from a storage-battery carried on the floor of

the vehicle. In the station where it belongs special wires hang from the ceiling just over the wagon, and the charging of the battery goes on while the wagon is out of use.

The author is indebted to The Hub Publishing Company, of New York, for much valuable information in connection with this article, and also for many of the new styles of vehicles above described, many of which were especially designed and drawn for publication in that journal.

Carriers, Hay: see Hay-Carriers.

Carving Machine: see Routing Machine.

CARVING-MACHINES. In carving-machines may be included several types: those which merely rout, all the work being of the same depth and being cut by rotating cutters that work with their sides as well as their ends; those in which rotating cutters work patterns which have varying depths, and which, instead of consisting of channels having flat bottoms, have curving bottoms or tops; those which do the same class of work as is just mentioned by fixed knives instead of by rotating cutters; and those which by rotating cutters produce patterns which have contours in planes both parallel to the face of the material worked and at right angles therewith.

A carving-machine made by P. Pryibil for making flat work from a pattern consists in the main of a horizontal table having lengthwise traverse upon the main bed of the machine, a vertical frame at one end of the latter, and a system of jointed arms borne by the upright frame, and bearing at its outer end a routing or carving tool. The movements of this cutting tool are directed by a forming pin which is moved over the pattern—in which it does not differ from several other carving-machines—but in this one the cutter-frame is balanced and swings upon pivots, the table rolls on a track, and the belts are endless, thus doing away with the tremor which is inseparable from laced belts. There is a spiral spring which tends to bring the cutter-frame in one direction, thus rendering it difficult for the operator to cut too deeply into the work. The cutter-frame has vertical adjustment in the upright frame by a hand-wheel; the table has cross-feed in like manner. The machine will take in about 36 in. wide, one half being taken up by the work and the other by the pattern; but the length taken in by it is unlimited.

The Albee Routing-Machine, while having in its most simple form the ordinary arm and elbow attachment to a post or wheel, and capable of doing regular routing, has attachments which permit it to be used for carving, fluting, twisting, etc. The work is made fast to the table for the purpose of lessening the risk of maiming the operator, and doing away with the labor of moving the work; there is a lever by which the cutter may be raised and lowered at will. The table has a raising and lowering attachment by which both ends are moved at once, a screw and hand-wheel working on knuckle or toggle levers, which bear the opposite ends of the table-top. The carving attachment consists in the main of a guide attached to the table to hold the piece of molding or other work that is to be carved or fluted, and of another guide by which the cutter may be driven in parallel or other lines at right angles or at any other angle to the piece to be worked. A twisting attachment permits working spirally on pieces of any desired diameter, the lengthwise feed being automatic and regular, and variable by change of gear-wheels.

The Pryibil Twist-Machine, shown in Fig. 1, is a recent production for making all kinds of spiral or rope moldings, either straight, tapered, curved, or so-called oval. It will make right, left, or pineapple cuts, and will also do straight fluting; and a further extension of its range is in its capacity to cut from one to six threads on a piece, and to make any degree of twist, from one turn in 1½ in. to one in 10½ in. of length. The cutters which it employs are similar in shape and arrangement to those used on variety shapers, and are held between collars; but they are so arranged that the knives have a peculiar action, cutting from outside in. Whether the twist be right or left handed, the cutters rotate in the same direction. At starting upon its design the makers considered the fact that machines having solid cutter-heads and using knives formed to outline, like those on straight molding-machines, cut across the work at the angle of twist, and, by cutting one side of the body against the grain, were apt to make rough work. In avoiding this, machines having two cutter-heads and two sets of knives, placed close together and turning in opposite directions, have been used; but this requires the employment of two sets of spindles, pulleys, bearings, belts, etc.; of course, more than doubling the care required to effect adjustment. In addition to this there are required two separate and complete sets of cutters where right and left twists are required; and, as each set comprises four slotted

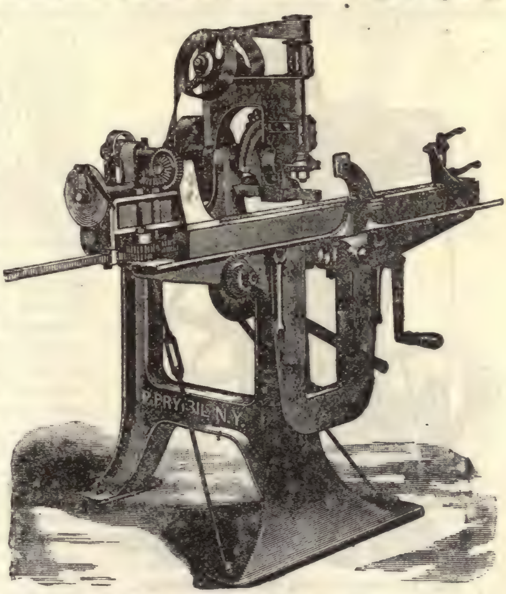


Fig. 1.—Pryibil twist-machine.

and formed knives, the expense is considerable in this direction alone. But it is in the substitution of one set for another, and the difficult setting of all of them to match, that the principal disadvantage of the two-cutter system lies; besides which there is an additional trouble in the difficulty and danger of running two sets of knives side by side at 5,000 turns per minute, close enough together to have their cuts meet, yet without the cutters themselves touching each other. This makes the double fly-cutter undesirable, particularly where work in great variety and quantity has to be turned out at a low price.

The end-cutter, or boring-cutter, is another class of machine originally devised to produce smooth work; there being a single knife at the end of a spindle that is set square with the work, and which at the beginning of the cut is fed endwise, causing the cutter to bore to proper depth, after which it cuts sidewise. In this class of machine there are required both right and left hand knives, as with the double-fly cutter, and both they and the belt must be changed to suit right and left hand twists. There being but limited space between the two bodies on a piece of twist work, there is room for only one knife, and, as this can not be set at such an angle as to cut properly, it practically scrapes its way through the stock—a slow operation, calling for very frequent resharpening of the cutting-tool. The Pryibil machine uses both classes of cutters, the boring and the scraping tools, but the former are used only in that class of double spiral work where there is a space between two separate and disconnected spirals, each one twisted around the other, but not touching it. Fly-cutters can not do such work as this, but can do every other class of work. They have been made to do square work by setting them sidewise to their collars at an angle of 45°, causing them to cut with a shearing action from the outside of the work toward the center. As the knives are made from bar-steel, and are straight-faced and right and left, the two of a pair can be placed together face to face to compare their outline in grinding. By this system the difficulty is much reduced of cutting the two sides of the body to match at the top; but still further accuracy in this particular is got by an adjustment to the machine by which the work may be swung around to match the cutter in a moment without stopping the cutter. The same movement enables double and curved tapers—that is, tapers that are large in the middle and small at both ends—to be made by the use of suitable wooden forms. This machine is particularly well adapted to making screen-work of the "Moorish" pattern, consisting of long, thin spirals interwoven like wire-netting. Such work is ordinarily considered very difficult to make, by reason of the trouble in getting the thin sticks to stand up against the cut. In the subject of this illustration there is a steady rest directly opposite the cutter, holding a wooden block, through which a hole is bored, fitting the stick to be cut spiral. The cutter works its own way through the block to the work, and, as the cutter and the block maintain their relative position while the work feeds along, the latter can not spring or break. The spindle-frame of this machine is counterbalanced so as to swing easily from right to left, and is fed to the work by a quick lever-motion. Changes of twist are produced by turning two wheels on a screw, according to a table attached to the machine; the change from right to left is effected by placing the gears on one or the other side of a rack.

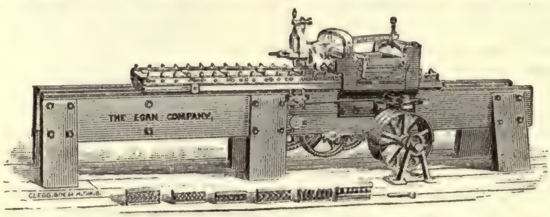


FIG. 2.—Egan carved-molding machine.

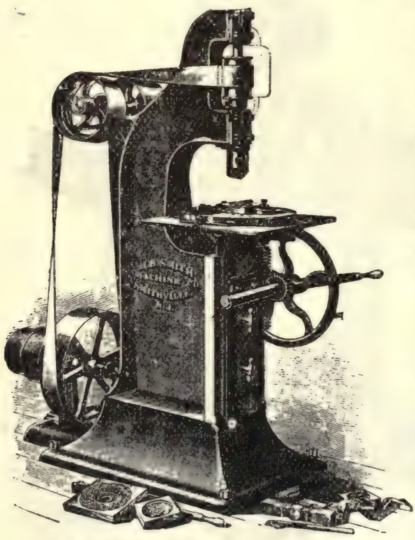


FIG. 3.—Geometrical carving-machine.

The Egan Carved-Molding Machine.—A machine for making carved moldings, and built by the Egan Co., is shown in Fig. 2, its function being to cut moldings without a pattern and leave sharp corners. There is a frame of heavy timbers, much like that of an ordinary Daniell's wood-planer, with suitable heavy iron slides at the top for the bed to travel over. The lower part of the bed has spur and rack gearing, giving an automatic motion back and forth to the carriage or bed which bears the work. The travel of the bed is regulatable, so that long or short moldings may be made at will. The head or tool-holder is pivoted on horizontal studs at the right of the housing of the machine, and is made to raise and lower when cams borne by the front end of its saddle come into contact with upward-projecting studs on the sides of the traveling-bed. The shape of the knives, which are fixed, governs the style of the molding, of course modified by the action of the cams and studs in throwing them in and out of cut as the material is fed along under the knives, and by the

position of the knives with regard to the tool-post. The bed traveling back and forth, and the tool-post and its knives working up and down as the cams pass over the studs on the carriage, produce the proper combination of movements to make carved moldings.

A Geometrical Carving and Corner-Block Machine, Fig. 3, patented by S. Y. Kittle, is used in making interior wood-decorations for ceilings, such as corner-pieces, center-pieces, borders, etc. There is a frame which has a square table or box with a flaring base, and a continuation having a gap somewhat in the manner of a band-saw or drill-press frame; this carries a vertical router-spindle, the pulley of which has one bearing above and one below, the belt passing over two idler-pulleys at the back of the frame and down over the main pulley which is at the bottom of the machine, at the back, the shaft running fore and aft, and hence at right angles to the router pulley-shaft and the idler-shaft. The table has vertical motion by a rack and pinion, and horizontal adjustment, as well as tipping motion for certain classes of work. There are adjustable stops to regulate the depth of cut; and the table has an index for dividing and regulating its circular movement. There are suitable clamps and jaws for centering and holding down the blocks, and the whole table is counterbalanced, so as to move more readily up and down by a hand-lever. The router-shaft pulley is covered by a casing which protects the operator, and keeps oil from being slung over him and the work. By this machine, work of the class done in metal by a rose-engine or geometrical lathe may be effected; and by an attachment the operator can cut designs on material of any length, as in the case of long boards on mantel-pieces. Another attachment is for routing or duplicating operations in line for fancy moldings, consisting of a table with rack and pinion-feed, that may be fed along by a hand-wheel, or by a lever and ratchet, as desired.

CENTERING-MACHINE. A new double-spindle centering-machine, made by the D. E. Whiton Machine Co., New London, Conn., is shown in Fig 1. Two spindles are provided, one of which carries a drill, and the other a reamer or countersink. They are driven at different speeds, by a single belt, over a pulley whose center is in line with the center of the lateral movement of the head. Both spindles are balanced by springs as in sensitive drills, and are successively advanced to their respective cuts by a feeding-lever.

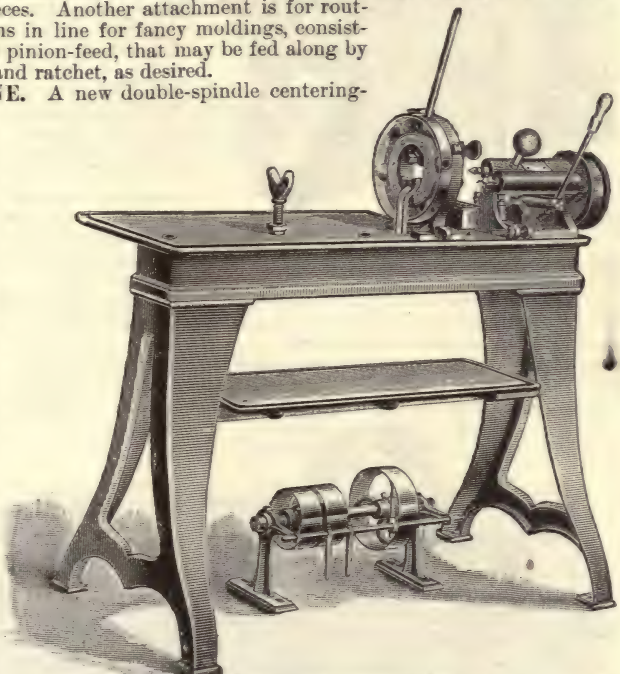


Fig. 1.—Double-spindle centering-machine.

The machine is so arranged that neither spindle can be advanced by the feeding-lever except at the central point. The moment this advance is begun no lateral movement of the head is possible, nor is lateral movement again possible until the return of the spindle to its normal withdrawn position. A support is provided for the front end of the bar while it is being inserted in the chuck, in addition to the V-shaped rest for the rear end. The chuck is thereby made self-centering.

Centrifugal Extractor: see Creamers. **Centrifugal Pumps**: see Pumps, Rotary.
Centrifugal Reels: see Milling Machinery, Grain.
Chain Machine: see Rope-Making Machines.
Channeling: see Quarrying Machines.
Check Valves: see Valves. **Check Rower**: see Seeders and Drills.
Chemical Fire-Engine: see Engines, Fire, Chemical.
Chlorinating Machine: see Mills, Gold.
Chrome Steel: see Alloys.
Clay Filter: see Filters.

CLAY-WORKING MACHINERY. Apparatus for the treatment and handling of clay prior to its manufacture into bricks, tiles, etc. When clay is thoroughly and evenly tempered, it is then in best condition to make a good brick. Hence, since clay in its natural state is found in such a variety of conditions, the question of properly preparing it for the machine, with the least expense and the best results, becomes a matter of importance. It is seldom, if ever, the case that a bed of clay is found with moisture so evenly distributed in it that it is just in the right condition to work the season through. A very common as well as successful plan is to soak the clay in pits. Two pits are used, one being filled and soaked while the

other is being made into brick. Clay that is either too dry or too wet does not work satisfactorily alone, or as well, alternately mixed, as if the entire mass was uniform in temper when put into the machine. This difficulty is overcome by carefully soaking in clay-pits, or by equivalent preparation by pug-mills and crushers. When pits are used, the clay should be leveled off in the pits, and the lumps broken up after every few loads. A sufficient amount of water should then be thrown upon it, and this operation repeated until the pit is full. By this means the clay will neither be too soft at the bottom or at the top, but evenly tempered throughout. A little experience and observation will suffice to obtain good results in tempering the clay. To facilitate the convenience of soaking the clay-pit, a tank should be erected high enough so that the water can be thrown from it by the use of a hose, and in this way one person can easily supply the necessary amount of water without any hindrance to the other part of the work. In a very few cases the clay comes from the bank in the right condition to go at once into the machine. In this case it is best to have a platform arranged over the machine, on a level with the top, so that the clay can be dumped on this platform, and with the least possible labor thrown into the machine. In dry weather, when the clay-bank has a tendency to dry up badly, it is a very good practice to arrange to partially soak the clay in the bank by means of throwing water over the bank, or if possible irrigate it by digging trenches over the bank and allowing the water to flow through them.

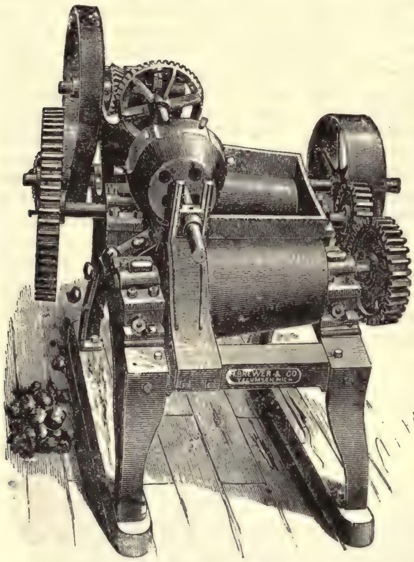


FIG. 1.—Clay-crusher.

CLAY-CRUSHERS AND GRANULATORS.—Machines for crushing and granulating clay embody rotary crushing-rolls, and are so constructed as automatically to separate out the stones naturally contained in the material.

The Brewer Clay-Crusher, manufactured by Messrs. H. Brewer & Co., of Tecumseh, Mich., is illustrated in Fig. 1. This apparatus has two conical rolls, 22 in. in length, with diameters respectively

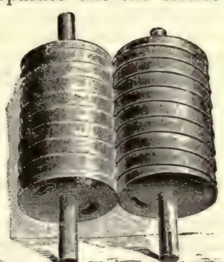


FIG. 3.—Detail.

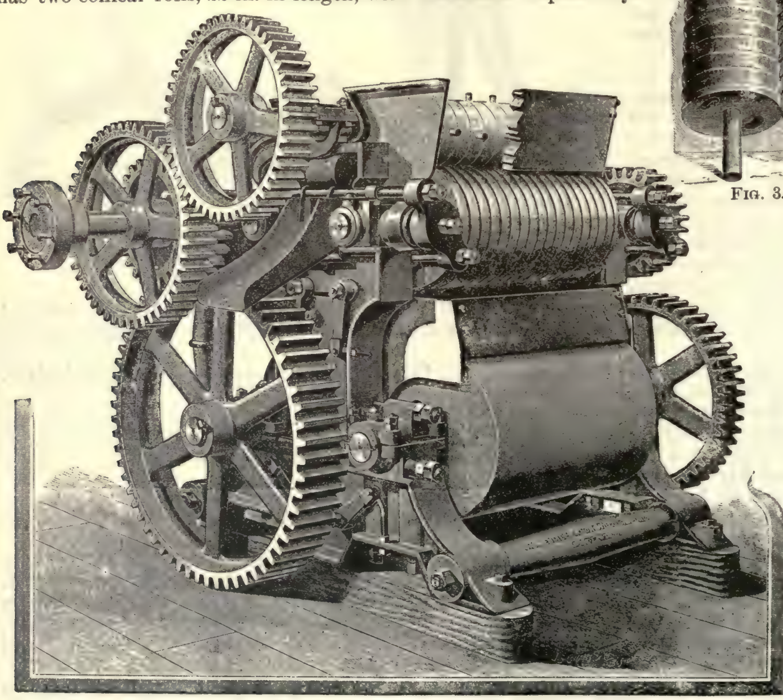


FIG. 2.—Penfield clay-crusher.

of 14 in. and 17 in. at the ends. The stones are separated from the clay, and are discharged at one end of the rolls. The rolls are made of chilled castings, and are run at unequal speeds, the effect being to disintegrate the clay more thoroughly. Such of the clay as does not pass between the rolls moves toward the transverse crushing-roll, which is placed near their larger ends. The unequal revolutions ot the two crushing-rolls, taken in connection with the fact that the periphery of each roll has a varying speed throughout its entire length—owing to their conical form—has proved that all the clay, except the very large lumps, will be drawn between the crushing-rolls before it reaches the transverse roll. The periphery of the transverse roll is of irregular form, and is also provided with teeth, or spurs, both of which assist in breaking up the clay. The transverse roll revolves with its upper surface turning toward the moving clay, and any lumps or clods of clay with which it may come in contact, whether moist or dry, are readily broken up and forced between the two crushing-rolls.

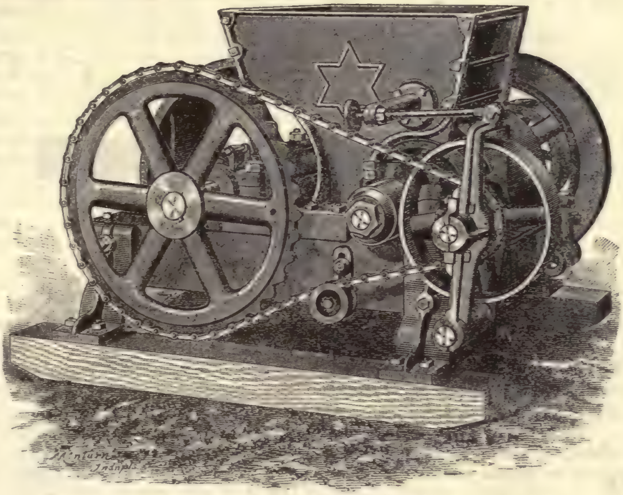


FIG. 4.—Clay disintegrator.

The Penfield Clay-Crusher, manufactured by Messrs. J. W. Penfield & Son, of Willoughby, Ohio, is represented in Fig. 2. The peculiar construction of the crushing-rollers in this machine will be noted in Fig 3. On each there is a broad spiral corrugation, right and left hand respectively, which extends the entire length of the roll. The projection on one roll fits into the corresponding depression on the other, so that the rolls can always be set closely together, and any wear be thus taken up. When running at a moderate speed, the clay passes freely through the rollers and is crushed, while all stones too large to be at once crushed are quickly passed to one end and out of the crusher through an automatic gate. The rollers run at different speeds; usually one about twice as fast as the other. The mode of applying this so-called differential principle to corrugated rolls is exceedingly ingenious; the necessity

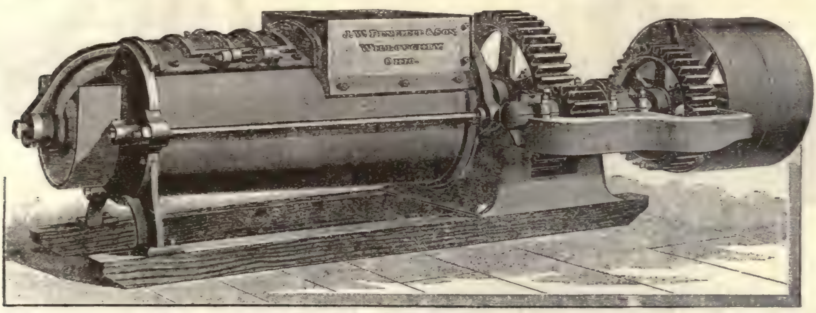


FIG. 5.—Pug-mill.

of exact matching of the corrugations, and, at the same time, of driving the rolls at different speeds, resulting in a problem not easy to solve. The high-speed roll is made with a single thread or corrugation running at $1\frac{1}{2}$-in. pitch; the slow-roll has a double-thread or corrugation running at 3-in. pitch, twice as great; hence, the corrugations on the former will advance the same in two turns as the latter in one. In the machine represented in Fig. 2 the upper rollers are corrugated, and are 17 in. in diameter and 36 in. in length. Heavy car-springs are arranged between the boxes of the adjustable roller. The lower rollers are smooth, 24 in. in diameter and 36 in. long, and are geared to run at differential motion. The height of this machine is 5 ft. 6 in., and it crushes clay sufficient for from 40,000 to 60,000 bricks per day.

The Ports Clay Disintegrator, illustrated in Fig. 4, is especially adapted for tough, stony clay, which it pulverizes by removing successive portions from a mass thrown into the hopper; the action being similar to that of a file or grater. The mechanism consists of a cutting cylinder, revolving from 500 to 800 revolutions per minute, in combination with a cylinder of larger diameter, revolving at from 20 to 50 revolutions per minute. The clay is carried through and ground entirely by the action of the high-speed cylinder, the low-speed cylinder

acting simply as a feed-roller. By the differential speed, and by the cutting action of projecting bars on the roll, the clay is finely divided.

Pug-Mills often receive clay in a crude state just as it comes from the bank, and reduce and pug it, to bring it to tempered condition. They are also employed to mix two or more kinds of clay together, or to combine it with sand, sawdust, grout, or other material. Fig. 5 represents a Penfield pug-mill, capable of pugging the clay for from 40,000 to 50,000 bricks per day. The tempering-tub is made of heavy boiler-plate, is 5 ft. long, 29 in. in diameter at the large end, tapering down to 25 in. at the small end, and is provided with a large hinged door. The main shaft is of forged steel, $4\frac{1}{4}$ in. in diameter where the gears are attached, and hammered square where the knives fit on. The pugging-shaft is provided with a wrought washer and brass wear-plates at the back end, receiving the end-thrust of shaft. The journals are all long, and shafting proportionately heavy.

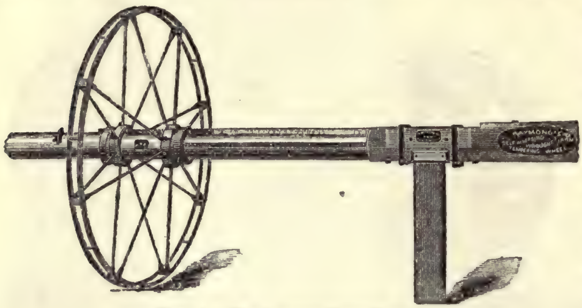


Fig. 6.—Clay tempering-wheel.

Tempering-Wheels are employed for mixing and tempering the clay in the pit. Raymond's wheel, illustrated in Fig. 6, has 16 spokes and a double tire. It is operated in the pit by either steam or horse power. The clay is worked between the spokes as well as between the tires. By an automatic arrangement of the rod and pinion, the wheel is drawn back and forth on the shaft, changing its position with each revolution, and reversing itself both at the outer and inner edge of the pit.

Cleaning Machine: see Flax Machines.

Clocks: see Watches and Clocks.

CLUTCHES AND COUPLINGS. *The Hill Friction-Clutch Pulley* is shown in Fig. 1. The pulley is cast with a rim projecting from the arms, inside of and concentric with the ordinary rim, which rim is gripped on both sides by wooden blocks. These are moved by a combination of toggles, whose action is shown in the sectional view.

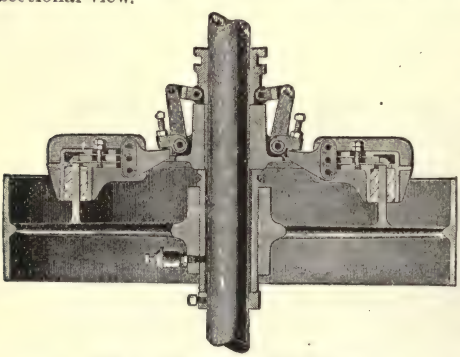


Fig. 1.—Hill friction-clutch pulley.

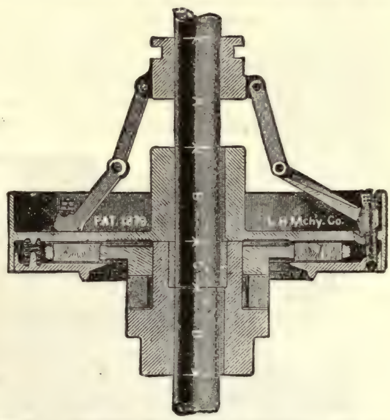


Fig. 2.—Link Belt Eng. Co.'s disk friction-clutch.

The Link-Belt Engineering Co.'s Disk Friction-Clutch is shown in Fig. 2; figure showing the clutch in engagement, and figure disengaged. It consists of a plate-center pulley, containing beneath its rim on one side the toggle-lever mechanism, and on the other the clamping-plate, embracing a disk which is provided with projecting hard-wood plugs. This disk is loosely interlocked with square jaws on the hub of the pulley, wheel, or coupling.

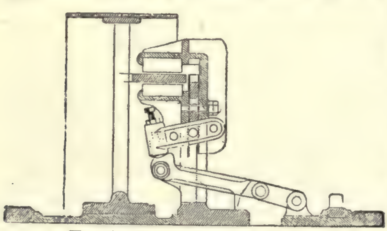


Fig. 3.—Brock friction-clutch.

The Brock Friction-Clutch, a portion of which is shown in the sectional view (Fig. 3), has a rim which is grasped on the inner and outer sides by the clutch members, which are shod with seasoned maple. The radial motion of the jaws or clutch members is produced by the sliding piece (seen to the right of the pulley) being pushed toward the clutch or pulley, giving motion to angled levers, which force the upper or outer jaws inwardly and the inner jaws outwardly, until they grip firmly both sides of the rim. Moving

the sliding piece away from the clutch, in the position shown in cut, disengages the jaws or frictional surfaces.

The Weston Safety Ratchet, as applied to crabs, winches, and similar hoisting apparatus, is shown in Fig 4. The principle is based upon the combined use of a friction-clutch with a ratchet wheel and pawl in such a manner that the action of the weight tightens the clutch and prevents all possibility of accidental release. The reverse motion of the handle releases the clutch and permits the load to follow, but any variation in the speed of the crank-motion is followed by a corresponding variation in the barrel-movement, and when the motion of the crank is stopped, either intentionally or accidentally, the barrel also stops. Referring to the cut, *D* is a section of a spur-pinion suitable to be used in connection with any light train of gearing. At *C* is a ratchet-wheel with which a pawl engages, and which can thus only revolve freely in one direction. Between the pinion *D* and the ratchet-wheel *C* are several friction disks, the alternate ones being connected with pinion and ratchet-wheel, and giving enough friction surface to hold the two parts firmly together as a unit when they are forced into close frictional contact. Both pinion and ratchet-wheel are loose upon the shaft *A*, and are placed between two collars. One collar, *B*, is pinned fast to the shaft, and is a plain collar. The other collar, *E*, has a helix formed upon its side, and there is a corresponding helix upon the hub of the pinion upon that side. This collar *E* is also pinned fast to the shaft, so that there is but slight play between the parts, just enough to permit the engagement or release of the friction-disks. When the shaft *A*, carrying with it the collar *E*, is revolved, the top moving toward the observer, the helix on the collar acts as a circular wedge upon the helix on the pinion-hub, and forces the friction-disks tightly together, and also tightens the whole series upon the shaft; and any motion given to the shaft *A* is transmitted through the pinion *D*, just as if it were keyed fast. The same action takes place when the load attempts to rotate the pinion backward. When it is desired to lower the load, the shaft *A* is turned beakward. The ratchet-wheel can not revolve in that direction, as it is held by the pawl, and, as the pinion is held by the friction-disks, the shaft alone is turned, carrying with it the collar *E*. This motion releases the wedge action of the helix, and reduces the pressure upon the disks, and hence the load can now pull the pinion backward, the alternate disks slipping upon each other. Any tendency for the load to turn the pinion faster than the shaft and collar *E* at once creates an increase in the friction between the disks, and so the pinion can not run down any faster than the motion of the crank and shaft, and, if the crank is for any reason let go, the friction-disks will at once tighten and hold the load.

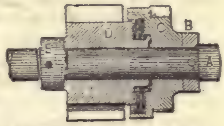


FIG. 4.—Weston safety ratchet.

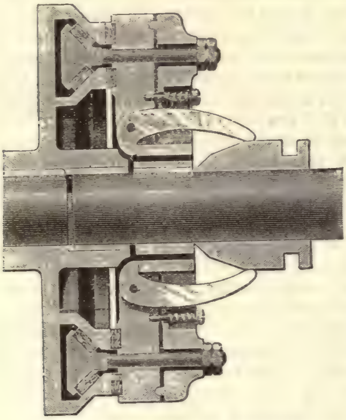


FIG. 5.—Frisbie's cut-off coupling.

Frisbie's Friction-Clutch (Fig. 5) is used in connection with a hoisting-drum, such as is used in pile-drivers and like hoisting machinery. The sectional view shows its use as a cut-off coupling. The rim of the clutch, as shown, contains a groove with internal beveled surfaces, each of which is pressed by wooden blocks which are drawn outward

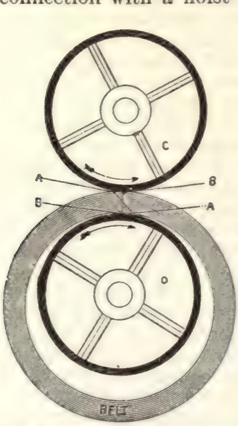


FIG. 6.—Frictional belt-gearing.

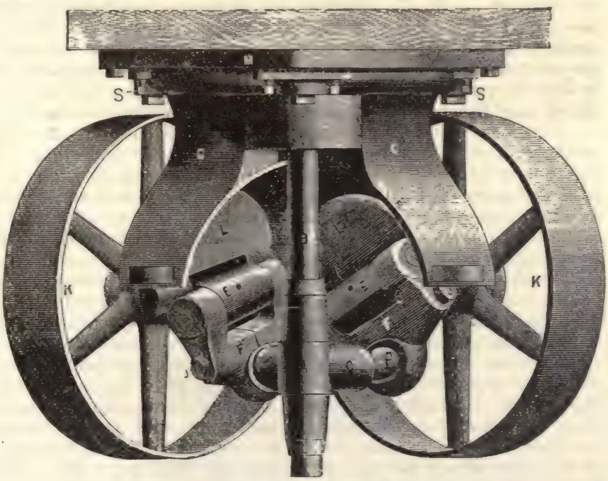


FIG. 7.—Almond's right-angled coupling.

by the operation of a bent arm-lever, the long arm of which rides upon a cone, which is moved along the shaft by the shifting lever.

Frictional Belt-Gearing.—A new system of transmitting power by belts and pulleys, made by the Evans Friction Cone Co., of Boston, is shown in Fig. 6. The power is transmitted from one pulley to another, with which it is nearly in contact, by a ring or belt of leather, which is gripped between the adjacent surfaces of the pulleys, and transmits the power by friction. The diagram (Fig. 6) shows the principle of the system. The diametrical line *B B* shows the points of contact of the belt when the pulleys are idle, but little pressure remaining upon the belt. The oblique line *A A* shows the points of contact of the belt when the pulleys are in motion. The force of the driving pulley *C* is transmitted to the outer face of the pulley *D*, in a line obliquely with the axis of the driven pulley.

Almond's Right-angled Coupling.—Fig. 7 shows a form of shaft-coupling made by T. R. Almond, Brooklyn, N. Y., for transmitting motion between two shafts at right angles to each other. The sleeve *A*, which slides on the post *B*, carries two studs *C* at right angles to each other, each of which is connected by a ball-and-cup joint to the forked piece *F*, which oscillates on pins formed on the piece *E*, which rotates with the pulley *K*. Motion being given to either pulley *K*, it causes the stud *C* on the same side to be carried upward and downward, and to be oscillated back and forth as the sleeve *A* moves on the post *B*. On the other side these motions are all reproduced, causing the other pulley *K* to rotate. The coupling is inclosed in a metal case, which holds a supply of oil sufficient to last from one to two years.

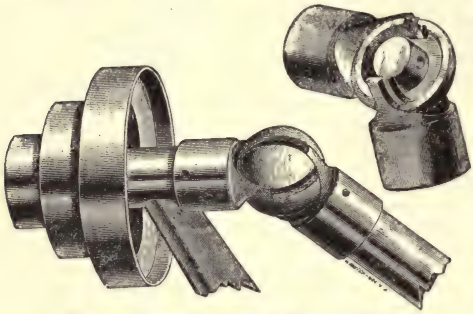


FIG. 8.—States Machine Co.'s angle-joint.

The States Machine Co.'s Angle-Joint is shown in Fig. 8. One joint will operate within an angle of 110°, and a pair used jointly will operate within 70°. The sectional view clearly shows the construction. The end of each of the coupled shafts is fitted with a piece carrying a semicircular projection T-shaped in section. These projections fit into T-shaped grooves cut at right angles in a steel ball. The ball is made in pieces for the purpose of putting the coupling together. The coupling is especially adapted for feeding devices of machine-tools where the power has to be transmitted at a varying angle.

COAL-BREAKERS. Coal-breakers and the machinery used in them for the preparation of anthracite coal for the market have been ably described by Mr. Eckley B. Coxe, in the *Transactions of the American Institute of Mining Engineers*, xix, 398, of which this article is largely an abstract. Anthracite coal as it comes from the mines is not marketable. The "run of mine" can not, as in the case of bituminous coal, be sold. Anthracite, being very compact and practically free from volatile combustible matter, burns only at the surface, and it is, therefore, deemed important to have the lumps as nearly of a uniform size as possible, so that between them a large amount of surface will remain exposed to the action of the air without checking the draft too much or allowing enough air to pass to cool the coal below the ignition-point. In other words, if the pieces of coal of the size of a chestnut and smaller are mixed with lumps of the size of an egg, they fill the air-passages and prevent a free draft. It has long been recognized, therefore, that one of the most important points in preparation is to have a uniform sizing, and also to make as large a number of different sizes as can be produced without too great expense. It is also essential to remove all the dust, which is of little or no use at present, and depreciates the value of coal in the market.

Mixed with the pure coal, large amounts of slate, "slate-coal" and "bony coal" generally occur. The term "slate-coal" is commonly used to designate lumps composed partly of coal and partly of slate, in which the pure coal occurs in such large masses that, by rebreaking, pieces of pure coal of marketable sizes can be obtained economically; and "bony coal" to designate lumps in which the coal and slate are so interstratified that they can not be separated economically by mechanical preparation; also coal in which the impurities are present in such high percentages as to destroy or greatly diminish its market value. In other words, slate-coal is coal from which, by breaking and preparation, a certain amount of pure coal can be obtained: bony coal is coal which can not be economically rendered more pure by mechanical preparation, although it may be used for certain purposes in its crude condition.

The problem is, to remove the impurities as completely as possible. Of course, when the slate occurs in separate pieces, it should be eliminated without further breaking. But the slate-coal must be broken into smaller pieces to separate the slaty portion from the coal. It is generally impossible to sell all the larger lumps which come from the mines, and machinery must be provided for breaking them up into such sizes as the market requires.

The coal coming from the mines should be divided into its various sizes, and the free slate in each size should be removed, before any breaking is done. This can be done either by hand-labor or by mechanical means. In the first case the coal is passed along chutes, on the sides of which men and boys are placed who pick out the slate, and in some cases the bony and slate-coal, and allow the pure coal to pass into the pockets. The mechanical slating of the coal depends upon one or more of three physical characteristics of the coal and slate: the difference in their specific gravity; the difference of the forms in which they break; and the

difference of their angle of friction, or, in other words, the difference in the angle of a chute, lined with stone or iron, down which the coal or slate will slide without any increase of velocity. As a rule, slate will not slide down a chute which will carry coal.

Machinery for Sizing Coal.—This may be divided into two classes: fixed or movable bars, and fixed or movable screens. In the first, the openings through which the coal falls are much longer than they are wide, while in the second the ratio of the length to the width of openings does not generally vary much from unity. In special cases the first class may be used to take out dust or fine coal; otherwise, they are seldom employed, except for large coal, unless when exact sizing is not important. The reason is, that long, flat pieces fall out with the cubical pieces of much smaller dimensions, rendering the coal thus sized unsightly, inconvenient to handle in the furnace, etc. There are three types of the first class now in common use: 1. The adjustable bars, supported at both ends. 2. The finger-bars, supported at one end. 3. The oscillating bars.

The Adjustable Bars are, as the name implies, a series of bars, whose position can be adjusted, over which the coal to be sized is made to slide longitudinally. The ends of the bars are made V-shaped, and they fit into similar grooves on the transverse pieces by which they are supported, so that the bars can be placed at required distances from each other varying with the width of the bases of the triangles, which is usually about 4 in. The bars are generally made 4 ft. long, but, of course, can be made of any size.

The Finger-Bars are an improvement upon the ordinary bars, and have been recently introduced. In using the continuous bars, part of the dirt and fine coal is often carried over the bar, and is delivered in the chute at the lower end, instead of falling through; and as the spaces between the bars are parallel and closed at the lower end, long pieces often wedge and catch, particularly at the bottom, thus necessitating a frequent cleaning. Of the finger-bars, the lower end is entirely free, and the bars are narrower there than at the upper end, and any lump that may wedge is likely to be loosened by the first lump which strikes it. Upon the vertical portion at the upper end of the bars are two half-holes, by which they are bolted to the beam or bar-bearings.

The Movable or Oscillating Bars consists essentially of a series of double bars, placed sufficiently far apart to allow coal of the required size to pass between the bars of each pair. The lower ends of the bars have semicircular bearings, which fit over a horizontal shaft, while the upper ends are supported upon two round steel rollers. The bars are oscillated back and forth by eccentrics on the main driving-shaft, which are so connected with the bars that the motion of the latter is approximately horizontal. The throw given them is about 3 in. On the main or driving shaft there are two eccentrics, placed 180° apart. The bars are flat on top, the extreme lower end being rounded off to allow the coal to roll off easily; then for a certain distance they are horizontal, rising finally in a curve, the center of which is upward, to the point where the coal arrives upon the bars. The upper ends of the bars, which are carried by the rollers, extend under the chute whence the coal is fed.

Fixed Screens may be either fixed or movable. The former consists simply of an inclined plane, formed either of woven wire screens or punched or cast plates, with round, square, elliptical, etc., holes. The coal in this case is allowed to slide or roll by gravity, not too rapidly, down this plane. The larger pieces pass over, and the smaller fall through. By placing several screens with openings of decreasing size underneath one another, or a series with openings of increasing size, in the same chute below one another, any desired number of sizes can be made. The objection to these is that their capacity is limited, the sizing is imperfect, and the screens clog more or less.

Movable Screens.—The movable screens are among the most important parts of a breaker. They are of two types. In the first type the screening surface forms a cylinder and revolves about its axis. In the other type the screening surface is approximately horizontal, and the motion and action are very similar to that of an ordinary hand-sieve. In many cases the screen is moved backward and forward in an approximately horizontal plane. This motion, combined with the inclination of the sieve, causes the coal which is fed on the higher part of the screen to travel gradually across it, allowing the smaller particles to fall through. In other cases the approximately horizontal screen receives a gyratory motion, like the motion a molder gives to his sieve when screening his sand. Its great advantage is that the whole surface of the screen is constantly in action, while in the revolving screen of say 5 ft. in diameter only about 8 in. of the 16 ft. circumference is at any one time in action, unless the screen is overcrowded, and the revolving of the screen acts like an elevator and tends to throw the coal back into the screen.

The problem of constructing a gyrating screen, when the screen is to be large and must make a great number of sizes, is to support it in such a manner that it will gyrate easily and safely, and at the same time be self-contained, so that the centrifugal force will be counterbalanced and will not shake the building. The method consists essentially in supporting one horizontal plane upon another by means of three or more double cones, while the motion of gyration is given to the upper plate by a crank upon a shaft passing through and journaled in the lower plates. The cones roll freely in a prescribed path on the lower plate, while the upper plate moves upon the other end of the double cone, its relative motion to that of the cone being the same as that of the bottom plate. The result is that every point on the upper plate describes a circle of the same diameter (in coal-screens generally about 4 in.), but no two circles have the same center.

The cones may be guided in various ways. By one method the upper and lower plates are made with an annular, truncated, V-shaped track, which fits into a corresponding groove in

the cone. In other cases the guiding is done by an annular grove in the running-plate and a corresponding annular enlargement of the cone at the outer edge. When, however, the screens are run at high speed, there is a tendency in the double cone to fly from the center; the surface, therefore, on which the cones roll is sometimes made conical, so that the weight of the screen has a tendency to force the cone toward the center, thus counteracting the centrifugal force to a great extent. In this type the circumferential surface of the enlargement is very broad, and has a good bearing against the outer surface of the groove in the running-plates. This form of cone is well suited to resist any tendency of the centrifugal force to throw it out.

There are other types of cones in which the guiding is done by a ball-and-socket joint at the two points of the cones. Both the running-plates and cones in this type are made in the lathe, and are all fitted to gauge. The same precautions are taken in the lower right cut as in the upper left cut to counteract the effect of the centrifugal force.

In the case of single gyrating screens the screen-box is commonly made about 4 ft. wide and 6 ft. long, inside measurement. The number of shelves varies from two to six, depend-

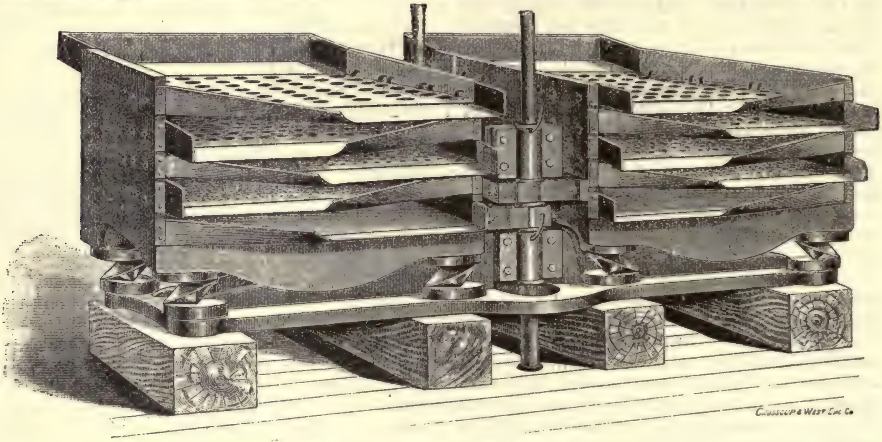


FIG. 1.—Double gyrating screen.

ing upon the material to be screened. The smaller the size of coal, the closer to each other the screens can be put. The boxes are made from 1 to 2 ft. deep. The double gyrating screen (Fig. 1) is a combination of two single screens, driven by two parallel vertical shafts, each shaft having two eccentrics upon it close together, and placed 180° apart. In the latest forms of these screens counterbalances on a shaft connected with the outside end of each box have been added, whereby strains on the eccentrics of the driving-shafts are lessened, and the screens are made to run more steadily at a higher rate of speed. It has been found that the best results in screening were obtained at from 140 to 145 gyrations per minute. The screens are sometimes made of cast-iron plate when the holes are large, but punched steel is generally preferred, being lighter. Copper is occasionally used for small sizes.

Machinery for Breaking Coal.—For breaking up the coal two methods are used. When the lumps are large and the pieces of slate attached to them are of such a character as to render it economical, the larger lumps are broken by hand, the men using picks made for that purpose. In this way large pieces of pure coal or pure slate can often be obtained; but by far the larger portion of the breaking is done by rolls.

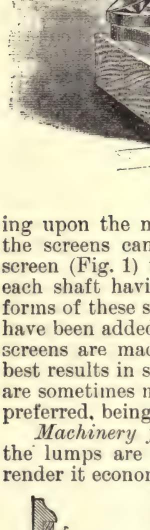


FIG. 2.—Corrugated rolls.

The rolls used in breaking coal are of two kinds, those with pointed teeth and those known as corrugated rolls (Fig. 2), in which the teeth are continuous from one end to the other. In the latter there are no points, and the ends of the teeth are slightly rounded, the part doing the work being cast in chills, so as to give greater endurance.

In the operation of a roll as ordinarily constructed—i. e., with pointed teeth—the point of one of the teeth inserts itself into a lump of coal which is passing through the rolls, and breaks it very much as the stroke of a pick would do; that is, the lines of fracture radiate approximately from the point where the tooth strikes the lump of coal. If two pieces of round iron are placed parallel to one another, and at such a distance apart that a piece of coal will just be supported by them, and if a third piece of round iron, placed midway between and in a direction parallel to and above the other two, is then brought down upon the coal, the piece of coal will break near the middle like a piece of wood subjected to a load in the middle too great for it to bear. The result of this action is generally to break the lump into two pieces of nearly the same size, which is the result desired.

In breaking coal, as in crushing ore, experiment has shown that successive reductions give the most satisfactory results—i. e., produce the minimum amount of fines—and most breakers are equipped upon this principle. It is not necessary, consequently, to change the distance

between the centers of the shafts of the rolls after the proper distance for most economical breaking has once been determined, and the rolls are made with fixed bearings. Where it is desired to crush coal to various sizes with the same set of rolls, those with adjustable bearings are used.

Taper rolls, the construction of which is shown in Fig. 3, are sometimes used where a small quantity of a number of different sizes is to be broken up at once. At the upper or larger end the rolls will take steamboat; a little farther from the end they will take broken; a little farther they will take egg; and a little farther stove. When the coal to be broken up is of different sizes, and the quantity not large, these rolls may be economical, but the tendency of practice at the best breakers is to increase the number of rolls, having a different roll for each size to be broken.

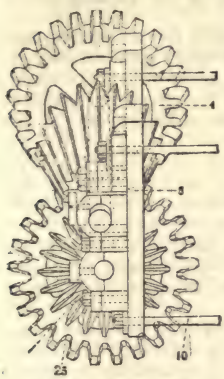


FIG. 3.—Taper rolls.

Jigs.—The jigs used in washing coal are modifications of the ordinary Hartz jig used in ore-dressing, differing only in size, capacity, and minor details of construction. The principle of coal-washing, moreover, is identical with that of ore-dressing, except that in the latter heavy mineral is separated from lighter gangue, which is thrown away, while in the former light coal is to be separated from heavier slate or pyrites. The coal-jigs in general use are invariably of the side-piston type, and consist of a single compartment. In the jigs used at the Drifton breaker (Fig. 4) the sieves are 5 ft. long and 3 ft. wide, and the pistons of the same size. The bottom of the jig is semicircular. The coal to be washed is fed on to the jig at the side of the sieve next the piston, over an adjustable plate (6), the lower end of which is placed as near the sieve as is consistent with a free discharge of the coal. The coal passes out under this, spreading over the sieve, its constituents arranging themselves according to their specific gravities—the slate and pyrites at the bottom and the pure coal at the top. At the outside of the sieve the pure coal is skimmed off from the top by a series of flat strips of iron carried on two rows of link-belt chains, running over a wheel (34), or by some similar device. The coal is thus dragged up an inclined plane and discharged, the water carried with it draining back to the jig. The slate passes out through an opening in the side of the jig just above the sieve, which is regulated by an adjustable slide, into a flat cast-iron hopper (9). The bottom of this hopper is closed by a gate, which allows neither slate nor water to escape. This gate is opened at proper intervals, the upper opening from the sieve to the hopper being closed at the same time, and the accumulated slate discharged from the hopper into a trough, whence it is removed by a suitable conveyor after having been inspected.

For jigging fine coal similar jigs are used, but the sieves are bedded with feldspar or like material of approximately the same specific gravity. In jigs of this class the slate discharges through a goose-neck outlet instead of one of the kind shown in Fig. 4, or else through the bedding and sieve into the hutch below, whence it can be drawn through a proper gate.

Automatic Slate-Pickers.—These depend for their action upon the fact that, while the coal generally breaks into cubical masses, the pieces of slate of the same length and width are of very much less thickness. Hence, if a quantity of slate and coal which has been passed through a screen and properly sized, the slate, if placed edgewise, would drop through a slit over which the coal would pass. There are two types of automatic slate-pickers: one, intended to be placed in a chute and to be fixed; and the other, to be placed in the discharge-slip of a gyrating screen and gyrated.

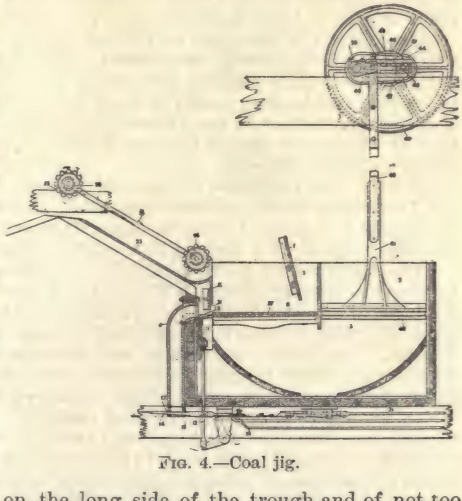


FIG. 4.—Coal jig.

The fixed slate-picker consists essentially of a series of V-troughs of iron cast in one piece, one side of the V being shorter and at right angles to the other. The lower half of the casting has a taper slit in the short side. The slit is so arranged that anything lying on the long side of the trough and of not too great height can slide out through it. Any lump which is thicker than the height of the slit will of course be retained in the trough. The slits widen as they approach the lower end, and the part of the casting below the cross-bar hangs freely, so that there is nothing to stop a piece from sliding through the slit. This slate-picker is placed in an ordinary trough or chute down which the coal slides. It receives pitch enough to allow the coal to slide over freely, but with not too great velocity. As the coal and slate come down the chutes, each lump places itself in one or other of the grooves or troughs, which are made a little wider than the largest lump of the size for which the slate-picker is to be employed. As the lumps slide down, all the flatter pieces tend to pass out through the slit on the side, while the cubical

lumps go over. Should a piece catch in the slit in consequence of the increase in height toward the end, some one of the pieces which follow will generally knock it loose, so that it does not remain and block the slits. The slits if made parallel would soon clog. The flat pieces, which are mostly slate, and which fall through the taper slit, pass over a chute or picking-table or any convenient place, where they are examined by a boy, who takes out any flat coal that may come through with the slate. The size and taper of the slit, the pitch of the picker, the width of the troughs, the length of the upper and the lower portion of the casting, vary with the size of the coal, nature of slate, etc.

The Gyrating Automatic Slate-Picker is made in the same way, with this exception, that only the part with the slit is used. This is placed on the discharge-chute attached to a gyrating screen. The pickers are made in two patterns, to be used according as the screen gyrates in one direction or the other. They must be so arranged that the gyrating motion of the screen has a tendency to throw the coal and slate against the short high side. In this way the latter is thrown out and passes to a jig or picking-table.

A third method of removing slate mechanically is used in several breakers in the Wyoming region. It consists essentially of an inclined plane, down which the lumps of coal and slate are allowed to slide freely. The plane may be covered with iron, stone, or slate. The angle is such that the slate will slide down uniformly while the velocity of the coal increases. There is a gap at the end of the inclined plane, over which the coal jumps by virtue of the greater velocity acquired in sliding down the plane, while the slate, moving slowly, drops into it. There are a number of devices for changing the pitch of the chute, the form of the opening, etc.

COAL-MINING MACHINES. The principal inducement to operators to use coal-cutting machinery in preference to mining by hand-labor is naturally due to a reduction in the cost of getting out the coal to be gained by the former method. With it, it is possible to effect a larger saving of coal than is possible by hand-labor, due to the small height of the undercut; also the number of men which have to be employed can be materially reduced. To get out the same amount of coal it is not necessary to keep as many working-places open in mines using machinery as it would be when employing hand labor, thus making it possible to have the working-places more concentrated, and thereby to save a large amount of expense in the form of dead-work, such as keeping open gangways. To give an approximate idea of the cost of mining with machinery as compared with hand-labor, it can be stated that a coal-cutter in the Hocking Valley is capable of giving an output of 80 to 85 tons a day. The price now paid for cutting coal by machines in rooms is 8 cents per ton; the price paid for loading coal after the cutting is 35 cents per ton. A miner can mine and load on an average 3 tons per day, being paid 70 cents per ton. This shows a cost of 43 cents per ton of coal mined by machines, against 70 cents mined by hand. To the former will have to be added wages for one engineer, fuel, interest and depreciation, and wear and tear of the plant. By working the machines day and night, however, these last items can be reduced to a minimum. This policy is being followed in most mines using machinery, as it enables a comparatively small machine-plant to give a large daily output. For example, should an output of 800 tons per day be required, and the machines be worked during the day only, ten coal-cutters (with the necessary engines), etc., would be required. By working day and night, five coal-cutters would be sufficient, as well as engines, generators or compressors, and ducts of half the size. The work of loading and hauling would be done during the day only. There are at present two general styles of coal-cutters in use; those using rotary cutters and those using reciprocating cutters, both of which have special features, which make it advisable to use one or the other, according to the nature of the coal.

Rotary Coal-Cutters.—The general features of rotary coal-cutters are as follows: the undercut is made by means of revolving tools, the axis around which they revolve being either a horizontal line parallel with the coal-cutter (cutter-bar), a horizontal line at right angles with the coal (augers), or a vertical line (chain-machine).

The machines in general consist of a stationary bed, upon which slides a movable frame bearing the cutting devices. The latter is gradually fed into the coal as the knives or tools cut the coal away in front of it. The motor (either compressed air or electric) is attached to the movable frame or to the stationary bed, suitable gearing transmitting the power to the cutting devices. The feed is automatic, and consists either of a screw and nut or rack and pinion. The best speed for feeding seems to be from one ninth to one tenth of an inch per revolution of the cutting devices; although for some coal this speed might be increased with advantage. An important feature of this style of coal-cutters is a proper device for withdrawing the coal-dirt or slack from the cut, to prevent the knives from becoming clogged.

In the room and pillar work in use in this country the coal is generally undercut the entire width of the room to a depth equal to the height of the vein. It takes about nine or ten cuts to accomplish this in a room 30 ft. wide. After the undercut is made, from three to four holes are drilled in the coal about two thirds of the height from the floor, but varying with the condition of the vein. These holes are filled with powder, and the coal shot down. After having been blasted down, the coal is loaded into the mine-cars by a set of miners, and the room is cleaned up for another set of cuts. While the process of drilling, blasting, and loading is going on, the coal-cutter is taken into another room prepared for it, and there again undercuts the coal the entire length of the room. The best part of the coal is generally at the bottom of the vein, and it is therefore desirable to save as much of this as possible. For this reason the "bearing-in," or cut, is often made in the fire-clay underlying the coal, if this is not too gritty, or in a slate-parting in the coal. If the latter is high up in the vein, the

machines can be worked from the bench—in other words, if the coal underlying the parting is allowed to remain down for a sufficient distance from the face of the room to allow the machines to rest on it while making the new cut. When undercutting in fire-clay, care is generally taken to cut partially in the coal, as the white clay adhering to the latter would decrease its value in the market. Wherever neither a suitable parting in the coal nor a fire-clay bottom exists, and it is desirable to get out the largest amount of lump-coal possible (especially in some of the small veins), the height of the cut has to be made as small as possible; it is, however, not advisable to reduce it below 3½ in., as otherwise it may not allow the coal to tumble over properly when shot down.

The amount of work a machine is capable of performing in a given time can be expressed in tons only when the thickness of the vein and the amount of impurities in the shape of partings, bony coal, or slate, etc., are known. A better method of designating the amount of work the coal-cutter is capable of performing in one day is by giving the number of cuts it can make, or the number of sq. ft. it can undercut. This daily work, of course, varies somewhat with the nature of the coal, whether the latter is hard or soft, or contains sulphur or bastard, the width of the workings, and the territory to be covered by one machine. The largest record so far made with rotary coal-cutters is said to have been 52 cuts in ten hours, or 950 sq. ft. undercut. The average work in the same mine in wide workings is 35 cuts, or 645 sq. ft., for narrow and wide workings 30 cuts, or 555 sq. ft.

When handled by expert men, and with not too hard coal, machines can make about 30 to 35 cuts a day in from nine to ten hours, making it necessary to prepare at least four rooms for each to work in.

With the exception of one type, all the rotary coal-cutters used in America are fastened down in proper position at the face of the coal to be undercut. They then make a cut in the coal to a certain depth, and of a width depending on that of the cutting device. The latter is then withdrawn, and the whole machine moved sidewise, and placed in position to make another cut adjoining the former. The time consumed in shifting the machines averages about 1½ min. To reduce this lost time as much as possible, it is advisable to undercut as many square feet as possible with one setting of the machine. There is, however, no advantage in making the cut deeper than the vein is high—that is, in a 5-ft. vein the cut would be 5 ft. deep, as otherwise the coal will not "shoot" down properly and tumble over. If the coal simply settles down in its former place, it is in a worse condition for mining than if it had not been undercut. Neither is it advisable to make the machines longer than required for the 6-ft. cut, as they would become too unwieldy. It is necessary to make the cut as wide as possible, so as to reduce the number of times the machine has to be shifted to cut the coal in a room of a certain width.

Handling Machines.—Coal-cutters are generally handled by two men only, and for this reason it is necessary to reduce the weight of the machines as much as possible. It must also be borne in mind that they are not only handled very roughly, but have to do very hard work, being at times forced through coal containing small streaks of sulphur, or other impurities, harder by far than the coal itself. Should these foreign substances occur very frequently in the "bearing-in seam"—that is, in that part of the coal in which the undercut is to be made—the reciprocating coal-cutters, of course, would be the proper machines to use. If, however, only small streaks of sulphur occur, the rotary coal-cutters are generally forced through them.

The main feature of a successful coal-cutter is great strength. To show that this is of far greater importance than lightness, the record is given of the time required to shift a 3,000-lb. machine, 36 seconds being the average time in six tests to shift the machine from one position to another. This, of course, is exceptionally quick, and it is not to be expected that men would be able to keep it up all day. This machine is probably the heaviest on the market, the motor alone on it weighing about 1,700 lbs.

It is hardly reasonable to expect that the machine can be shifted in less than a minute and a half as average for a day, no matter how light it is made, and this is being easily accomplished by expert men with machines having the abnormal weights given above.

To convey the machines from room to room they are mounted on small trucks and hauled by mules or horses from one place to the other. These trucks are generally provided with a suitable winch and chain, by means of which the machines can be readily loaded. The average time to do this is about 2 min. 45 sec.; the average time to unload the coal-cutter is 2 min. 35 sec.; and to get the machine ready for the cut will take 3 min. A quick record for this work is 1 min. 45 sec. to load, 1 min 30 sec. to unload, 1 min. 26 sec. to set and get ready for the cut. The time required to move the machine may be estimated as from 40 to 50 sec. for each room between the one cut and the one to be cut, although it may take all the way from 10 min. to an hour before a mule can be secured for this work. A truck so constructed that it can be operated by electricity in mines using the latter for power purposes is, therefore, very desirable.

Reciprocating Coal-Cutters.—The second style of machine used in America is the reciprocating coal-cutter. This is not capable of quite as rapid work as the rotary cutter. It has, however, some features which make it well adapted to certain kinds of coal and certain conditions. It has already been said that when the quantity of sulphur or similar substances is not too great in the bearing the seam of the coal, the rotary cutter can be used. Should sulphur occur in large quantities, and in the shape of what is called "sulphur balls," or "nigger-heads," it will be necessary to use reciprocating cutters. Another reason for using the latter machine in preference to the former in small veins can be found in the following:

In certain districts the miners are paid for the amount of lump coal mined. The small sizes of coal which pass through the screens having bars from 1⅛ to 1¼ in. apart—namely, nut, pea-coal, and slack—are clear profit to the operator. In these districts the royalties on the coal are also paid by the amount of lump coal mined. Whenever the small grades of coal, therefore, have a good market, it may be to the advantage of the operator to get out as much of these sizes as possible; and this can be done by means of the punching or reciprocating cutter. All the coal coming out of the cut made by the rotary machine is in the form of fine slack, and is not marketable; that coming out of the cut made by the punching-machine is generally in the shape of nut or pea coal. It is also necessary to make the height of the cut with the latter machines higher than that made by the rotary machine, to enable the tool to enter it and to undercut the coal to the proper depth. We present various improved forms of drills and coal-cutters.

FIG. 1.—Grim's coal-drill.

Grim's Coal-Drill (Fig. 1) is a simple form of hand-tool. When in position, the post is fastened securely to the roof and the floor of the mine. The nut through which the screw-rod turns is placed in any of the slots cut in the post in order to get the proper pitch of hole to be drilled. The steel bits slip into the socket at the end of the screw-rod, and are made in different lengths to suit the depth of hole to be drilled—for instance, if a 6-ft. hole is to be drilled, a steel bit 2 ft. long is first used, then it is replaced by a steel bit 4 ft. long, and finally by one 6 ft. long. The screw-rods or feed-bars are made with 6, 8, 10, 12, and 14 threads per inch, a range which fits the drill for all grades of hard coal or rock.

Watts' Drill for Boring and Reaming (Fig. 2) is specially adapted for boring into coal-banks. The machine is provided with an expansible bit, which remains in its closed or normal position while the hole is being bored. When a previously determined depth is reached, the bit is expanded to create a pocket at the end of the bore for the reception of a large amount of powder.

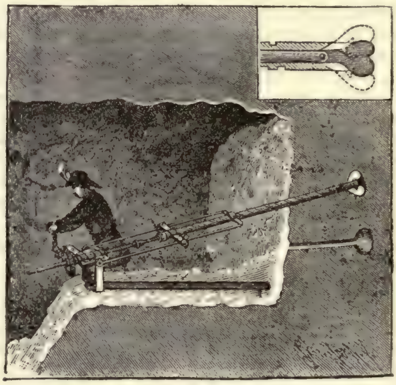


FIG. 2.—Watts' drill.

The figure shows an enlarged vertical section through the outer end of the auger-casing. The drive-shaft is provided with a longitudinal face-groove extending practically from end to end, and at its forward or inner extremity a socket is fastened to the shaft. At the rear of the guide-box a spur-wheel is connected with the drive-shaft by a feather passing through the hub and entering the groove of the shaft. By this means when the wheel is revolved to turn the shaft, the latter is free to move forward. When a hole has been drilled the desired depth, a thumb-screw is turned, which holds the clamp tightly to the frame and stops the forward movement of the casing without preventing the casing from turning. By further manipulation the casing becomes stationary and forces the bit-rod outward, thereby causing the bit-members to expand. When the pocket has been properly formed, the bit-rod is drawn backward, the bit assumes its normal position, and may be readily removed from the hole.

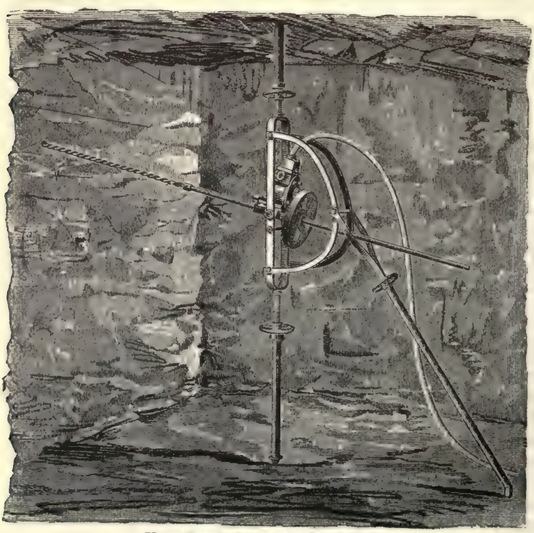


FIG. 3.—Jeffrey air-feed drill.

The Jeffrey Positive-Feed Coal-Drill consists of a small rotary engine hung in an upright frame, having joints at top and bottom to engage by adjusting screws with the roof and floor of the mine. This is supported by a dog or brace, to stiffen and hold the frame rigid as the auger-bit advances into the coal. Power is transmitted to this auger-bit or feed-bar through two gear-wheels. Attached to the engine are feed-nuts that open and close upon the feed-screw, which is 4 to 5 ft. in length, on one end of which is a square socket, into which is inserted the square end of the auger-bit. Two bits are used for convenience, one 3 ft. and the other 6 ft. long,

boring a hole $1\frac{3}{4}$ to 2 in. in diameter, as may be required. Seven, eight, and nine foot auger-bits are used to good advantage.

The Jeffrey Air-Feed Drill (Fig. 3) is similar in many respects to the positive-feed drill. In place of the feed-screw it has a feed-tube containing a piston, in the end of which is attached a suitable smooth feed-bar, 3 or 4 ft. in length, having a square socket, into which the auger is fastened. This tube arrangement is adjustable in all directions, so that the drill will accommodate itself to any mine. Only one hose connection is required to operate the drill, the feed to the tube and engine being controlled by means of a three-way valve. In operating, the engine is started first, after which the air is turned into the tube, which forces the piston forward until it travels the full length of the air-tube. The air is then shut off from the feed and allowed to escape, and the feed-bar is pushed back into the tube. The advantage this drill has over the screw-feed is that the air acts as a cushion when striking an unseen sulphur ball or rock, which allows the auger to advance more slowly, preventing strain upon the machine. The apparatus drills a hole $1\frac{1}{4}$ to 2 in. in diameter to a depth of 6 ft. in four minutes, and can be set and started in less than two minutes.

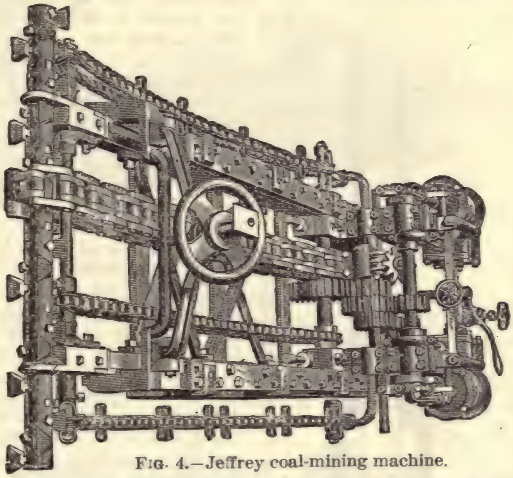


FIG. 4.—Jeffrey coal-mining machine.

The Jeffrey Air Coal-Mining Machine (Fig. 4) consists of a bed-frame occupying a space 2 ft. wide by 7 ft. 6 in. long, composed of two steel channel bars firmly braced, the top plates on each forming racks with their teeth downward, into which the feed-wheels of the sliding frame engage. Mounted upon and engaging with this bed-frame is a sliding frame, similarly braced, consisting mainly of two steel bars, upon which are mounted, at the rear ends, one double 5 in. $\times$ $5\frac{1}{2}$ in. engine, from which power is transmitted through straight gear and worm wheel to the rack, by means of which the sliding frame is fed forward. Upon the front end of this sliding frame is mounted the cutter-bar, held firmly by two solid steel shoes, with suitable brass boxes. The cutter-bar contains steel bits, held in place by set-screws. When the cutter-bar is revolved, these cutters or bits cover its entire face. The cutter-bar is revolved by an endless curved-link steel chain from the driving-shaft, and simultaneously advanced by the above mechanism into the coal or other material, to be undercut to the desired depth. The feed is thrown on and off by means of a lever. The cut under the coal, 5 to 6 ft. by 3 ft. 6 in., is made and the cutter-bar withdrawn in from four to six minutes. The machine is then moved over the length of the cutter-bar used, and another cut is made in the same manner. This is continued until the entire width of the room has been undercut, after which the machine is loaded on the truck and taken into another room. The makers claim that in some coal-veins the machines have cut at the rate of 130 to 150 lineal ft. face in ten hours to a depth of 6 ft.

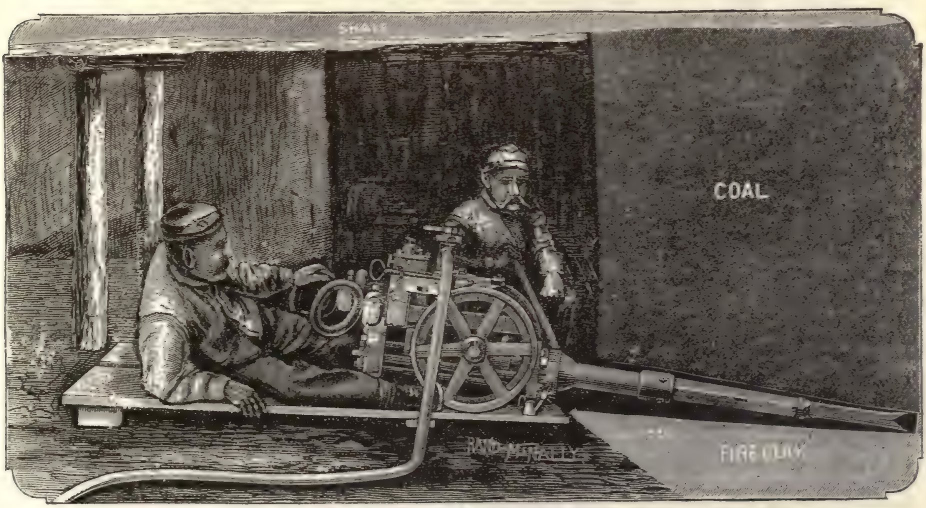


FIG. 5.—Harrison mining-machine.

The Harrison Mining-Machine.—Fig. 5 embodies a direct-acting engine mounted upon two wheels, the whole resting upon a board which is inclined toward the face of the coal. A pick shaped like a fish-tail is attached to the piston-rod. The valve is a rotary engine, and moves constantly and uninterruptedly when the throttle is open, whether the piston is stationary or in motion. Two handles are attached to the rear of the cylinder, which are used by the operator to direct the machine. The operator sits on the board, places his feet against the wheels, and takes hold of the handles. A channel is made under the face of the coal. The machine requires a maximum of 16 cub. ft. of air per minute at 45 lbs. pressure to run it, and an average of 15 cub. ft. each per minute when several machines are being run from one main pipe at the same time, which is fed to the machine through a 1-in. four-ply hose. The projectile weighs from 60 to 90 lbs.—according to the length of the rod—and strikes from 190 to 210 blows per minute. The total weight of the machine is from 570 to 620 lbs. The makers claim that from 25 to 50 sq. yds. of floor is the ordinary amount undercut by one machine each day. It has often undercut from 6 to 8 sq. yds. of floor per hour, cutting time, but all lost time for moving and other contingencies are included in this statement of a day's work.

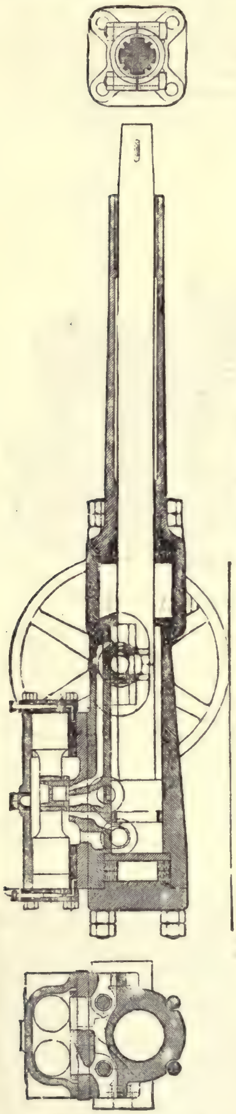


FIG. 6.—Sergeant coal-mining machine.

The Sergeant Coal-Mining Machine (Fig. 6) is made in two sizes: the standard machine—weight, 700 lbs.; length, 7 ft. 6 in. over all—which will undercut to a depth of 4½ ft.; and the light mining-machine—weight, 500 lbs.; length, 7 ft. over all—which will undercut to a depth of 5 ft. The light mining-machine is 15 in. high, and will mine coal from a 16-in. vein.

The distinctive features of this machine are as follows: No rotary or reciprocating engine is used to operate the valve, but a duplex slide-valve system, consisting of two valves in the same chest, independent of the action of the main piston. This valve motion is positive. Having no dead centers, it starts on turning on the air, and has no outside hand-wheels or moving parts. The stroke is made variable both in length and strength, and the force of blow and length of stroke are under instant control of the operator. The picks are of forged steel, with shanks made square and of full size where they enter the socket. Balancing is effected by loosening one nut and slipping the hub backward or forward in a slot cast in the side of the cylinder. The piston is made of forged steel, and is corrugated to prevent rocking or twisting. It is held in place by a composition metal sleeve which is bolted into the front head. The wheels are provided with large hub-bearings—4 in. in diameter—which eases the effect of the blow on the operator, and obviates lost motion. The movement back and forth on the board while running at full speed—190 to 250 double strokes per minute—is about ¾ in. The operator can swing the machine and direct the blow with one hand, and can work either right or left handed. The machine requires but little space and can be used successfully in narrow veins, around and between props, and wherever a miner can swing a pick.

The Jeffrey Electric Coal-Mining Machine is represented in side view with the cutter-bar withdrawn, in Fig. 7. It consists of a bed-frame occupying a space 2 ft. wide by 8 ft. 6 in. long, composed of two steel channel bars firmly braced, the top plates on each forming racks with their teeth downward, into which the feed-wheels of the sliding frame engage. Mounted upon and engaging with this bed-frame is a sliding frame, similarly braced, consisting mainly of two steel bars, upon which are mounted at the rear ends one electric motor, from which power is transmitted through straight gear and worm wheel to the rack, by means of which the sliding frame is fed forward. Upon the front end of this sliding frame is mounted the cutter-bar, held by two solid steel shoes, with brass boxes. The cutter-bar contains bits, made of tool-steel, held in place by set screws. When the cutter-bar is revolved, these cutters or bits cover its entire face. The cutter-bar is revolved by an endless, curved-link, steel chain from the driving-shaft, and, as it is revolved, is advanced by the above mechanism into the coal or other material to be undercut to the desired depth. The current required is from 30 to 50 ampères at a pressure of 220 volts; each motor is wound to develop fully 15 horse-power, though frequently in some veins of coal the machine only uses 30 ampères, or 7½ horse-power in making cuts. The armature of the motor is calculated to run at a speed of 1,000 revolutions per minute, from which the speed is reduced, so as to run the cutter-bar 200 revolutions per minute.

The Lechner Coal-Mining Machine is represented in Fig. 8. The machine is operated by either compressed air or electric power. It consists of a stationary frame held to the floor of

the mine by two jacks, out of which a sliding frame is advanced and withdrawn by means of a screw feed-rod. Around the front of this sliding frame passes an endless chain provided with steel cutters securely fastened in its solid links, suitable gearing driving the chain around at

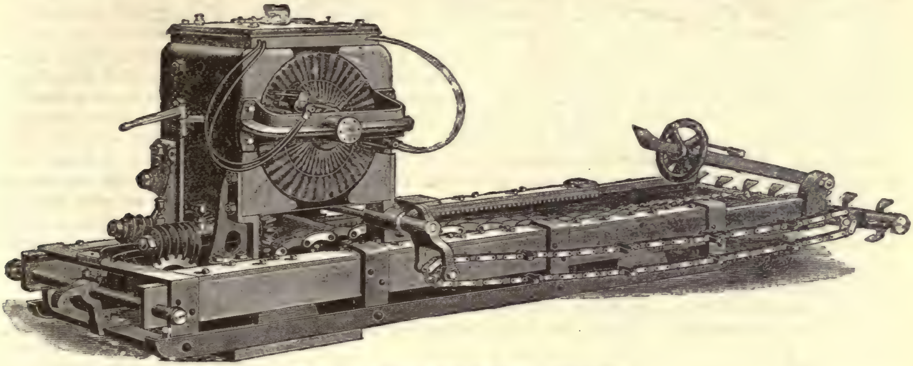


FIG. 7.—Electric coal-mining machine.

proper speed. A steadying drill, provided with a long bearing directly back to the cutting-head, passes forward with the sliding frame, and prevents any thrust caused by the side-cutting action of the chain. The standard machine is made to undercut 3½ ft. in width, 5 ft. in depth, and 3 in. in height, although these dimensions can be varied to suit special conditions. The size of the machine is 8½ ft. in length, 3½ ft. in width at the front end, 2½ ft. at the back end, and 22 in. in height. The weight of the standard machine for rope transmission is 1,050

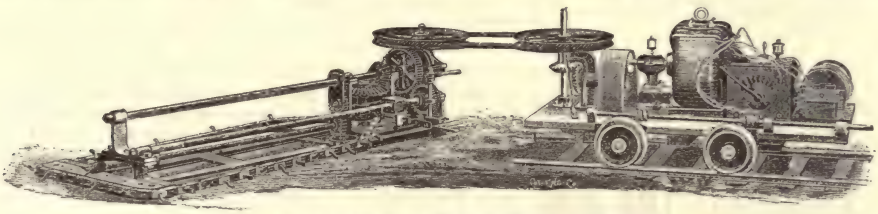


FIG. 8.—Lechner coal-mining machine.

lbs., with engines for compressed air 1,350 lbs., and with electric motor on frame of machine 1,800 lbs. It is claimed that in ordinary hard bituminous coal the undercut of 17½ sq. ft. is made within four minutes. The cutting chain is provided with 39 bits, or three sets of 13 each, following in the same plane; these bits are backed up with metal similar to a lathe or planer tool. The power required to drive the Lechner machine depends entirely on the work to be done.

Coal-Hoist: see Elevators. **Coal-Screens, Coal-Sizing Machinery, Coal-Washing Machinery**: see Coal-Breakers.

COKE-OVENS. The coke-ovens in use in the United States are almost exclusively of the old beehive type, 10½ ft. to 12 ft. in diameter and 5 ft. to 7 ft. in height. It is recognized that they are very wasteful, a large proportion of the value of the coal used being lost, but no attempt to recover this seems to have been generally made in this country. In 1887 there were in operation in the United States, in 279 establishments, 26,001 ovens, and 3,594 ovens in course of construction. These ovens consumed 11,859,753 tons of coal, producing 7,611,705 tons of coke, a percentage of 64·2. Dr. Bruno Terne, in a paper read before the Chemical Section of the Franklin Institute, October 20, 1891, estimates that on the basis of the work at two large establishments in France there should also have been saved 151,804,838 lbs. of sulphate of ammonia, or 12·8 lbs. per ton of coal, which, at 3 cents per lb., would have been worth $4,554,746, besides a large quantity of tar, amounting probably to nearly 2½ per cent of the weight of the coal. In England and on the Continent great progress has been made in the introduction of improved ovens for the recovery of these by-products, and many different kinds of ovens, designed for this purpose, have come into use.

The tardiness of the coke manufacturers of the United States in introducing improved ovens is inexplicable, as the flames from the tops of the beehive ovens which illumine the sky by night in the Connellsville region are a constant reminder of the present wasteful methods of coke manufacture. The greater first cost of the improved ovens is undoubtedly one of the reasons which has delayed their introduction, and it is also feared that, although the coke made by them may be of good quality, there may be a prejudice against it, as it lacks the silvery appearance of the Connellsville coke. The Hon. Carroll D. Wright, United States Commissioner of Labor Statistics, in his report, "Cost of Production; Iron, Steel, Coal, etc." (1890), gives the average cost of producing one ton of coke in 30 establishments in the United States

as follows: coal, \$1.219; labor, \$0.357; officials and clerks, \$0.028; supplies and repairs, \$0.058; taxes, \$0.005: total, \$1.667. The average amount of coal necessary to make one ton (2,000 lbs.) of coke was 3,110 lbs. With these figures the results obtained with the improved ovens described in the following paragraphs may be compared:

The Coppée Coke-Oven, which is extensively in use in Europe, is designed for coking finely divided coal. They are usually built in series of 30 or 40, and are worked in pairs. The ovens, which are 30 ft. long, 18 in. wide, and 4 ft. high, have each 28 vertical flues leading from the top through the partition-wall common to two ovens, to horizontal flues that pass longitudinally beneath the chambers. In these horizontal flues the gases from a freshly charged oven mix with those from one in which the coking is nearly complete, and combustion is effected by air admitted through three small openings. At each end of the oven are two iron doors. When a charge is completely coked, it is pushed out of the oven through the doors at one end by an engine and ram placed at the opposite end, this operation requiring about two minutes. The lower doors are then closed, and a fresh charge of coal fed in through three holes in the roof, which are covered by sliding doors. The charge is next leveled by means of rakes, the upper-end doors closed, and the operation resumed; the whole time, from opening the doors to discharge to closing them after a recharge, being but eight minutes. The coking occupies 24 hours, and the ovens are charged alternately at 12-hour intervals.

The Simon-Carvès Coke-Oven (Figs. 1 to 4), which is designed to save the by-products from coking, is somewhat similar in construction to the Coppée. There are charging-holes, *a*, *a'*, *a"*, in the roof of the oven, which is from 2 ft. to 2½ ft. wide and 5½ ft. to 6½ ft. high. The gases are drawn off through a pipe, *b*, *b'*, *b"*, which is provided with a regulating valve, whence they pass into a system of pipes common to from 30 to 50 ovens, kept cool by jets of water, in which the tar and ammoniacal liquors are condensed. The lower open end of the condensing pipes dip into a collector for the products of condensation, similar to those employed in gas-works. The gases from the condenser are then passed through scrubbers filled with wet coke, where the last traces of ammonia are removed. The uncondensed gases pass onward to the oven for heating purposes, entering through a horizontal aperture, *c*, *c'*, in the basal flue of the oven above a grate, *d*, that is filled with ignited coke-dust, while the air for combustion enters from below through the grate. Under the base of the oven the burning gases pass to and fro once, then rise between two adjacent ovens to the uppermost of the side-flues, *e*, *e'*, *e"*, and pass gradually downward to a large flue, *f*, which conveys them to the chimney. The duration of the coking is from 60 to 72 hours, in ovens of the smaller size. The yield of coke is said to be 75 per cent. At the Bességes iron-works, in France, in 1879, 46,902 tons of coal were coked in 85 ovens of this type. The amount of coke produced was 32,092 tons, or 70·55 per cent, together with 1,096 tons of tar (2·23 per cent) and 4,399 tons of ammoniacal liquor. The net gain, after deducting all expenses, and not counting the coke, was \$18,938. The consumption of coke-dust on the grate did not exceed 35 lbs. per ton of coke produced.

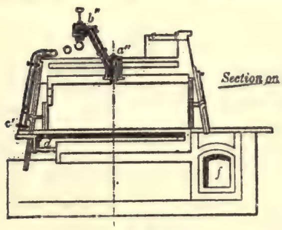


FIG. 1.

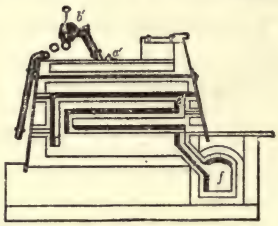


FIG. 2.

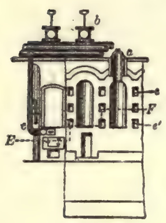


FIG. 3.

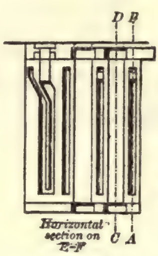


FIG. 4.

FIGS. 1 to 4.—Simon-Carvès coke-oven.

In the more recent Simon-Carvès ovens the fireplace and grate are dispensed with, and the oven is fired exclusively with the gases escaping condensation, these entering the lower flue at the place where the hearth used to be, while air is forced in through an annular pipe, being previously heated to 500° or 600° by being brought in contact with the hot flues conveying the spent gases away from the ovens. The two lower flues are thrown into one, and at the bottom flue, where the greatest heat is sustained, the walls are lined with fire-brick. The heated air admitted into the bottom flue is purposely insufficient for complete combustion of the gas introduced there, the further supply of hot air being obtained through the side-flues of the oven, the amount thus admitted being controlled by dampers. These ovens are made 23 ft. long, 6½ ft. high, and 19½ in. wide. Their capacity is about 5 tons of coal per charge, the time of coking lasting 48 hours. The cost of a Simon-Carvès oven to work about 480 tons per year, which is the capacity of an ordinary beehive oven, is \$845, complete with the coolers and all appliances. An ordinary beehive oven of this capacity costs but \$280. At Dyson & Co.'s Bear Park Colliery (Durham, England), according to Mr. S. A. Tuska, in an article "The Simon-Carvès Coking Process" (published by the author), a battery of 50 ovens cokes about 900 tons of coal per week. The analysis of this coal is as follows: Volatile matter, 27·69 per cent; fixed carbon, 68·44 per cent; sulphur, ·77 per cent; ash, 3·10 per cent. The yield in coke was 72·31 per cent; sulphate of ammonia, 9 tons per week, equivalent to ammoniacal water, 10 per cent of the coal, and of tar 6½ to 7½ gals. per ton of coal. The cost of labor for

coking and collecting by-products is estimated at 48 cents per ton of coke for a battery of 50 ovens, producing 107·5 tons of coke per 24 hours. A force of 33 men is required to operate a plant of this size.

The Pernolet Coke-Oven (Fig. 5) is very similar to the ordinary beehive oven, but it has a

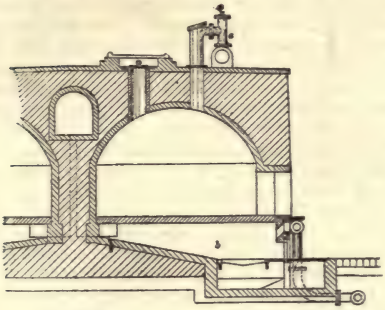


FIG. 5.—Pernolet coke-oven.

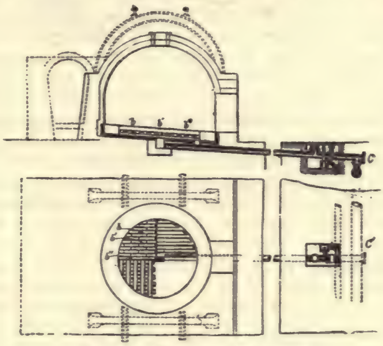


FIG. 6.—Jameson coke-oven.

fireplace and grate, and the gases are carried to an upper collecting tube *a*, and returned to the bottom flue *b*, where they are fired with solid fuel.

The Jameson Coke-Oven (Fig. 6) is an improvement on the ordinary beehive oven. Channels are made in the bottom of the oven, covered with perforated tiles, *b*, *b′*, *b″*, connected outside the oven with pipes leading to an apparatus, *c*, *c′*, for producing a slight suction, and for discharging the by-products when required. This is a very simple and inexpensive oven, and is said to have given very good results. According to Mills and Rowan (*Chemical Technology*, Fuel and its Applications, p. 185), a series of trials showed an average yield of $56\frac{1}{4}$ per cent coke, the average yield of ammonium sulphate and tarry oil being 6·3 lbs. and 6·2 gals. per ton (2,240 lbs.), respectively.

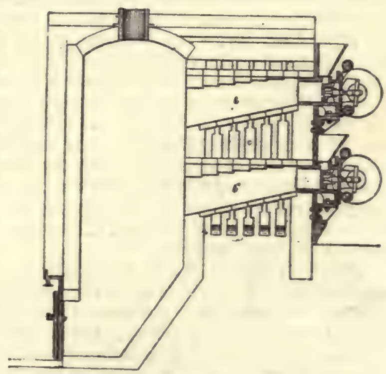


FIG. 7.—Lürmann coke oven.

The Lürmann Coke-Oven (Fig. 7) consists of a large chamber, *a*, opening into which are a number of coking-chambers, *b*. *b′*, into which fine coal is fed continuously from hoppers by a piston-feed, worked by a crank. The gaseous products pass into the chamber *a*, and, if required to be collected, are drawn off at an aperture at the top, and thence conducted into the spaces *c*, *c′*, under the retorts *b*, *b′*, where they are burned by means of air admitted for the purpose. The coke, as it falls from the ends of *b*, *b′*, is received in the chamber *a*, and is removed at intervals. This oven is continuous-working, and yields good, compact coke. It is very simple in construction, requiring no special fire-bricks, and is comparatively inexpensive.

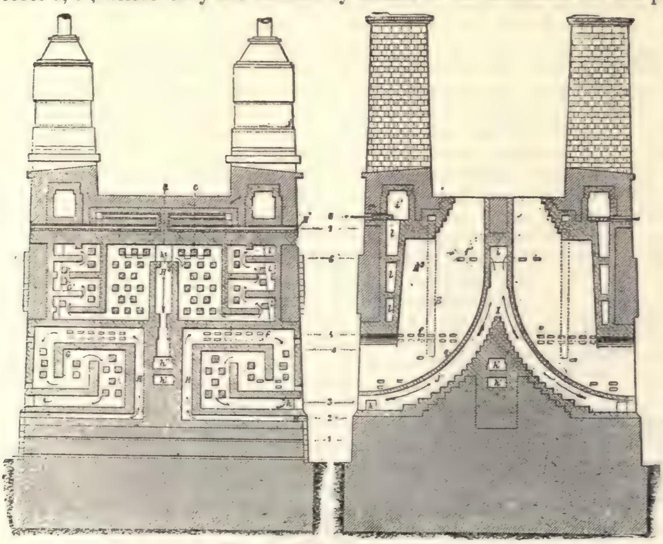


FIG. 8.—Bauer coke-oven.

The Bauer Coke-Oven (Fig. 8), which has been used with satisfactory results in France and Scotland, consists of alternate coke and regenerator chambers arranged side by side in a double row, while main flues for the combustion gases run along the tops of the chambers near the front,

and discharge into chimneys placed in convenient positions. The coking-chamber E, with a charging opening at the top, a curved back and base, and large discharge opening in front, communicates at the sides through openings $f\ f^1$, arranged at various heights, with the combustion-chamber G, where the gases are mixed with air admitted from the outside through passages H, forming a combustible gas of high heating power, which, by way of passage h, is conducted to the channel j below and along the back of the coking-chamber, and then through i into the upper chambers G^1, heating by their combustion the upper part of the walls of the coking-chamber E before they are discharged through the passages $l\ l$ into the main flue i^1.

The air before it mixes with the retort gases is heated by passing through long passages in contact with the heated walls, and the amount of air can be carefully regulated by slides. Additional air inlets with valves are provided near the top of the ovens at H^1, and the combustion gases can be also retarded in their flow to the chimney by valves at i^2. Fig. 1 is a cross-section through the combustion, and Fig. 2, through the coking-chambers. Forty of these ovens were erected at the works of the Carlton Iron Co., Ltd., in 1888 (*Engineering and Mining Journal*, l, 72). To obtain actual results of their work special trials were made in April, 1890, 124 tons of coal being used, of which 65 tons 16 cwt. was washed East Howle coal (fairly good coking coal), and 58 tons 4 cwt. unwashed coal from various collieries, varying considerably in quality and containing a large amount of volatile matter. Out of a total fixed carbon and ash of 69·65 in the coal, 69·44 per cent was returned as coke, the time required for coking being 24 hours. The proportion of large to small coke was satisfactory, there being only about 6 tons of small in a total of 86 tons of coke obtained from 124 tons of coal. This proportion of small coke is, however, considerably reduced, it is stated, in places where the traveling belt is used for the transit of the coke from the ovens to the trucks. The traveling belt consists of an endless metallic chain, supported on rollers and so arranged that it travels slowly in front of the discharge opening of the ovens. When the door of a chamber is opened the coke runs, owing to the shape of the coking-chamber, with but very little assistance from the attendant, on to the traveler, where it is quenched by water-sprays. The belt discharges the coke, practically without handling, into the trucks; thus a great saving of labor is effected, a foreman with three laborers attending to a group of 40 ovens. The experience so far gained seems to show that, owing to the high temperature obtained in the regenerative flues by burning the gases with a suitable admixture of atmospheric air, coals of almost any composition can either by themselves or as mixtures be used to produce sound hard coke suitable for blast-furnace work, and, since none but the volatile gases are utilized to produce the necessary heat, nearly the whole of the fixed carbon is converted into coke, while in addition any of the volatile gases not required for the coking process may be condensed and utilized for by-products. Dr. von Bauer, the inventor of this oven, has found that about 16 per cent of gases is necessary for the combustion.

The Otto Coke-Oven is essentially a combination of a coking-chamber with the Siemen's regenerator in order to heat the air, serving for the combustion of gas to as high a degree as possible. Where the gases are passed through a condenser, as is done in all cases where the by-products of coking are recovered, it is necessary to compensate for the cooling of the gas by using air at as high a temperature as possible for combustion with the gas. The Otto ovens are arranged in batteries, beneath which are the regenerative chambers connected by flues extending under the oven-floors, and equipped with the usual arrangement of reversing-valves, etc. Combustion of the gas and heated air from one regenerator takes place in one half of these bottom flues, the hot gases and flames rising through the vertical side flues which inclose the coking-chambers, and escaping by the other half of the bottom flues and the other regenerator. This process is reversed periodically in the manner usual with Siemens furnaces. The coking-chambers have openings at each end for withdrawing the coke, three openings in the roof for filling and two for the escape of the gases given off in coking. These latter are fitted with pipes and valves communicating with the main gas-pipe or receiver. Dr. C. Otto states (*Journal of the Iron and Steel Institute*, vol. ii, 1884, p. 520) that the regenerators for heating the air attain, in the working of these ovens, a temperature of 1,800° F., and that as a consequence it is found unnecessary to use all the gas given off from the valves for combustion. At a German coke-works, out of 24,700 cub. ft. of gas produced per coke-oven per day only 17,700 cub. ft. were required for combustion. The bottom and side flues become so hot that with a charge of 5 tons 13 cwt. of dry coal the coking process lasts only 48 hours, and sometimes less. With Westphalian coal the ammonia, reckoned as sulphate of ammonia, recovered, amounted to 1 per cent of the weight of the coal. The yield of coke from one coking-works amounted in seven months to an average of 3 per cent of the weight of coal used. By the daily treatment of 2 tons 14 cwt. of coal per oven, sufficient waste heat is obtained from every oven to heat 54 sq. ft. of boiler surface, which corresponds (according to Dr. Otto) with an evaporation of 1 lb. of water for every pound of coal coked.

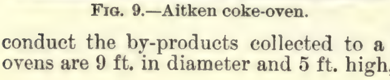


FIG. 9.—Aitken coke-oven.

The Aitken Coke-Oven (Fig. 9) is a beehive oven fitted with two pipes, a, a', for conveying the blast and gas from the condensers through small holes in the roof distributed equally around its circumference. Channels, b, b', b'', in the floor of the oven conduct the by-products collected to a pipe, c, which leads them to the condensers. The ovens are 9 ft. in diameter and 5 ft. high, from the floor to the charging hole in the roof.

The Semet-Solvay Coke-Oven (Fig. 10) consists of a central retort for coking, heated by the combustion of waste gas in flues which surround it. The coal is charged into the retort through the openings *A*, *A* in the roof. The waste gases escape through the opening *B* in

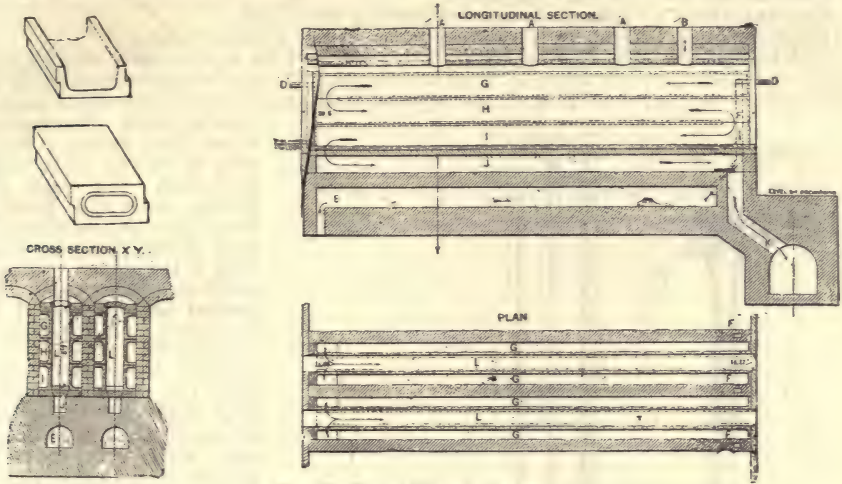


FIG. 10.—Semet-Solvay coke-oven.

the roof, and thence pass to condensers, where a considerable proportion of the volatile matter is recovered, as tar and sulphate of ammonia. The uncondensed gases are divided, the necessary amount for heating the retort being reconducted to the latter, and the remainder led off and burned beneath boilers. The gas returned to the oven passes through the pipes *D D′* into the upper of the three flues which stand on either side of each retort. Here it meets preheated air, entering through the flues *E* and *F*. Gas and air burn, sweep four times the length of the retort, and through the flues *G*, *H*, *I*, *J*, and pass thence under boilers through the flue *K*, and thence to the chimney, where their temperature is about 200° C. In order that the heat developed in the flues *G*, *H*, and *I* may pass readily to the charge coking in *L*, the walls of these flues are made very thin. Details of the pieces which compose these flues are shown in the upper left-hand corner of Fig. 10. The partition-walls which support the massive roof are wholly independent of these thin and necessarily rather fragile flue-pieces. The joints of the latter are made very thin, and are rebated, and the total extent of joint is made very small, in order to oppose the passage of the gas direct from the retort *L* into the flues *G*, *H*, and *I*, which would, of course, lessen the yield of by-products. The cast-iron end-doors of the retorts are shielded by double sheet-iron doors to retain the heat. The roof is made extremely thick, and the air is preheated by passing through the flue *E*, to cut off the escape of heat outward from the apparatus. To improve the combustion the gas is admitted partly at *D*, where it meets the whole of the air, and partly at *D′*. The little fireplaces usually employed for igniting the gas are suppressed, and it is thus possible to give the rational downward path to the burning gas and air.

A test of this oven was made at a French colliery with coal of the following composition: Water, 4·5 per cent; tar, 1·5 per cent; other volatile combustible, 10 to 11 per cent; ash and fixed carbon, 83 to 84 per cent. It yielded 81 to 82 per cent of coke, 13 to 15 lbs. of ammonia (recovered as sulphate of ammonia), and 31 to 34 lbs. of tar per 2,240 lbs. of coal charged. The outlay for labor in operating and maintaining ovens and condensers was not above 26 cents per ton of coke, or perhaps 6 cents more than in the ordinary Belgian oven, and the value of the by-products about 36 cents per ton of coke, so that the net gain was estimated at 30 cents per ton of coke. The oven cokes a 4-ton charge of coal in 22 hours. (See *Engineering and Mining Journal*, l, 165.)

Works for Reference.—For details concerning the manufacture of coke, see the following works: The Manufacture of Coke, by Joseph D. Weeks, 1885; Cost and Manufacture of Coke on the Simon-Carvès System, by R. Dixon, *Journal of the Iron and Steel Institute*, ii, No. 434, 1883; The Manufacture of Coke from Illinois Coal, by H. L. Luebbers; Utilization of By-Products in the Manufacture of Coke, by H. Simon, *Journal of Iron and Steel Institute*, i, No. 434, 1880; Treatise on Metallurgy, by F. Overman, 1882; Introduction to the Study of Metallurgy, by W. C. Roberts-Austen, 1891; Utilization of the By-Products of the Coke Industry, by Bruno Terne, *Journal of the Franklin Institute*, cxxxii, 375; *Chemical Technology*, vol. i, Fuels, by E. J. Mills and F. J. Rowan; The Physical Properties of Coke as a Fuel for the Blast Furnace, by John Fulton, *Transactions of the American Institute of Mining Engineers*, October, 1883; The Manufacture and Cost of Coke, by F. Koerner, John Fulton, and others, *Engineering and Mining Journal*, xlii, 291, 309, 330, 361, 362, 399, 415, 421, 434, 452; *Journal of the Iron and Steel Institute*, 1883, pp. 814 and 828; *Journal of the Society of Chemical Industry*, vols. 1883, 1884, and 1885; Recent Improvements in Coke Ovens, by MM. De Vaux and Eich, *Révue Universelle des Mines*, 1883.

Cold Saw: see Saws, Metal-Working. **Cold Storage**: see Ice-Making Machines.
Comber: see Cotton-Spinning Machinery.
Comparator: see Measuring Instruments.
Compressed Air: see Air, Compressed.
Concentrator: see Evaporator and Ore-Dressing Machinery.
Condenser: see Cotton-Gin, Ice-Making Machines and Engines, Steam.

CONDENSERS. *The Bulkley Injector-Condenser* is of the injector form, with its water supply and discharge-pipes arranged to act as a siphon. The condensing-water enters by the side nozzle, shown in the cut (Fig. 1), passing downward around the exhaust-nozzle in a thin circular sheet. The exhaust-steam thus enters a hollow cone of moving water, and is condensed. The water then passing down with great velocity through the contracted neck of the condenser draws with it the air and vapor into the discharge-pipe below. The general arrangement of the condenser and its pipes is shown in Fig. 1.

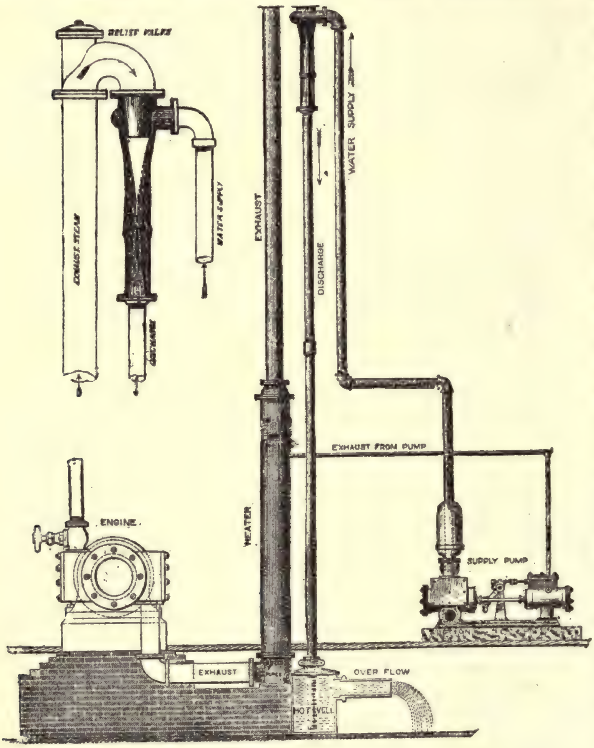


Fig. 1.—Bulkley injector-condenser.

Hill's System of Condensation for Pumping-Engines (Fig. 2) provides an ordinary surface-condenser arranged to take water from either the suction or discharge pipe of the main pumps, which water, after it has effected the vacuum in the condenser, is returned to the pipe from which it was taken. By the regulating-valve the amount of water passing through the main which is diverted into the condenser is regulated so that the least water capable of producing a given vacuum shall pass through the condenser, in order that the temperature of the hot well or water delivered from the condenser by the air-pump shall be as high as possible (this water being used as the feed to the boilers). By delivering more water to the condenser, a better vacuum may be obtained, with a corresponding reduction in the temperature of the contents of the hot well; but experience has shown that the gain in economy by the improved vacuum is more than counterbalanced by the reduced temperature of the feed to the boilers, and that a given vacuum of about 27 in. warrants maximum economy in all cases (as is usual) where the water of condensation in the hot well is pumped back into the boilers.

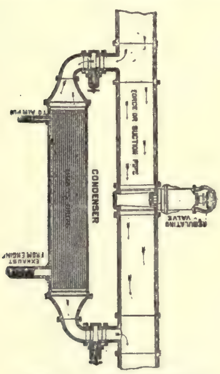


Fig. 2.—Hill's system.

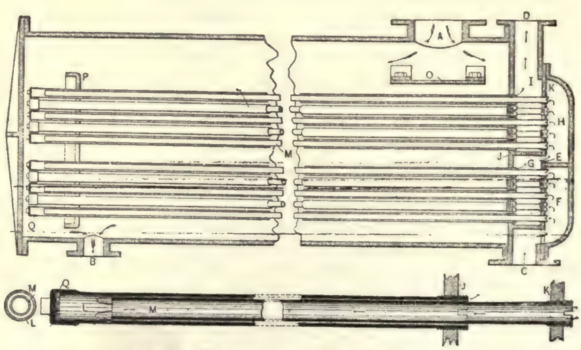


Fig. 3.—Wheeler's surface-condenser.

Wheeler's Surface-Condenser (Fig. 3).—In this condenser the exhaust steam from the engine

entering by the nozzle A, comes first in contact with the perforated scattering-plate O. The steam expanding in the top of the condenser, reduces its pressure and temperature before it comes in contact with the cold tubes. The water of condensation gravitates to the bottom, and passes out by the nozzle B to the air-pump. The cooling water is pumped into the compartment F through the nozzle C, and enters the small tubes as shown by the arrows. After traversing the small tubes, it returns through the annular spaces between the small and large tubes, and enters into compartment G; thence it passes into compartment H by the passage-way E. The water then circulates through the tubes of the upper section (in the same manner as described above), and finally passes out of condenser by the discharge-nozzle D. The lower part of the engraving shows one of the small and large tubes in section. The small tube M is expanded into the screw-head N, which latter screws into the head K. This small tube ends within a few inches of the cap G of the large tube L, thereby giving space for the water to reverse its direction before flowing back through the annular space between the two tubes. The end of the large tube that screws into the head J is drawn thick, so that coarse deep threads and a screw-driver slot can be cut; this latter is similar to the slot shown in N, which admits a tool for screwing up or unscrewing tubes from the tube-heads. When necessary to remove the tubes for cleaning or repairs, both small and large tubes can be drawn out from the same end of the condenser. After removing the small tube the large tube is unscrewed and drawn through the hole left vacant by the screw-head of the small tube—this hole being a little larger than the thick end of the large tube.

The Worthington "Independent Condenser" (Fig. 4) is a condensing apparatus consisting of a combination of a duplex pump with an injector-condenser. The illustration shows the general construction of the parts. A is the vapor-opening, to which is connected the pipe that conducts to the apparatus the steam or vapor that is to be condensed, and in which a vacuum is to be made and maintained. The injection-water used to produce the condensation of the steam or vapor is conveyed by a pipe attached to the injection-opening at B. Over the end of the spray-pipe C is placed a cone provided with wings that separate and distribute the water, and insure its complete admixture with the steam. This cone is adjustable.

The operation of the condensing apparatus is as follows: Steam being admitted to the cylinders K so as to set the pump in motion, a vacuum is formed in the condenser, the engine, cylinder, the connecting exhaust-pipe, and the injection-pipe. This causes the injection water to enter through the injection-pipe attached at B and spray-pipe C into the condenser-cone F. The main engine being then started, the exhaust steam enters through the exhaust-pipe at A, and, coming in contact with the cold water, is rapidly condensed. The velocity of the steam is communicated to the water, and the whole passes through the cone F into the pump G at a high velocity, carrying with it, in a thoroughly commingled condition, all the air or uncondensable vapor which enters the condenser with the steam. The mingled air and water are discharged by the pump through the valves and pipe at J, before sufficient time or space has been allowed for separation to occur.

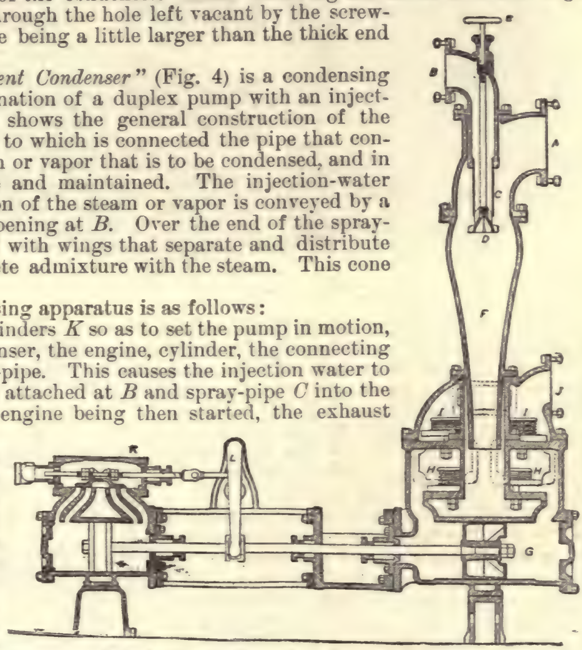


FIG. 4.—Worthington independent condenser.

Converter: see Mills, Silver, and Steel Manufacture.

Copper Steel: see Alloys.

Corliss Engine: see Engines, Steam.

Corn Harvester: see Harvesting Machines, Grain. **Planter**: see Seeders and Drills.

Cornish Rolls: see Ore-Crushing Machines.

Cotton Belts: see Belts. **Cotton Drills**: see Seeders and Drills. **Cotton-Picker**: see Harvester, Cotton. **Cotton Planter**: see Seeders and Drills. **Cotton-Press**; see Presses, Hay and Cotton.

COTTON-GIN. The improvements in cotton-gins during the past decade include novel forms of condensers and feeders, and the extended use of these attachments, and the invention of a new type of gin, in which a peculiarly formed working cylinder is substituted for the saws. It may not be generally known to cotton-planters that not only is all the dirt and dust taken from the cotton before spinning, but the exact amount of dirt in every bale is known and recorded, so that it is impossible at the present time to sell dirt for cotton. A first-class condenser will not only raise the grade of cotton, but will add greatly to the convenience of running the gins, and decrease dangers from fire. As the output of a gin depends materially upon the maintenance of the integrity of the roll, and this in turn upon the skill of the person feeding, it will be evident that an automatic feeding contrivance which substitutes regular machine-work for hand-labor should possess important economical advantages. In the following illustrations are represented the newest forms of standard gins.

The Eagle Gin is represented in perspective in Fig. 1, with the condenser and feeder

attached. Its interior construction is shown in the sectional view (Fig. 2). Among the new features is an adjustable grate-fall hollow, and an arrangement of the breast, which it is claimed prevents breaking of the roll. The object sought also was a perfectly smooth seed-board, presenting no angles to interfere with the easy turning of the roll. The bottom is formed of an iron plate sufficiently strong to hold the weight of the roll. This plate is attached to the body of the seed-board with hinges at its top edge, so that the bottom edge, which is notched to correspond with the saws, may swing in or out. The feeder is arranged on top of the gin. The feed-cylinder has the same speed as the gin-saws, and has strong, blunt pins to bring up the cotton. Behind this, and parallel with it, is another cylinder, moving slowly in the same direction, having wires in it bent backward. Between these two cylinders the cotton is completely opened, and the whole bolls broken apart, putting them in such condition that the gin will easily discharge them, at the same time knocking out a large amount of leaf and dirt. The condenser is simply a large drum, covered with cloth, and having a pressure-roller over it. These are inclosed in a case, reaching to the floor, leaving a few inches of the drum uncovered, from which the cotton is blown off in a continuous sheet by the brush. A hole is to be cut through the floor under the condenser, through which the air made by the brush is blown, carrying the dust with it.

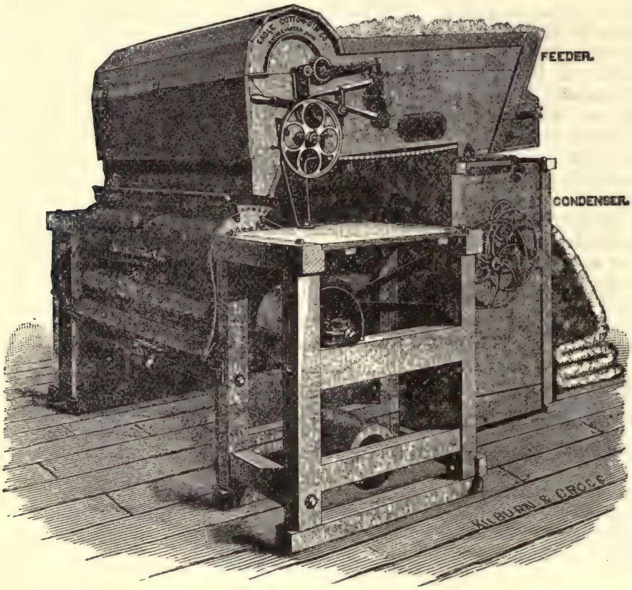


Fig. 1.—Eagle gin.

The Brown Gin is represented in section in Fig. 3. The feeder has an endless apron, *N*, by which the cotton is delivered to the roll-box, and is arranged to tilt back. The brush cylinder-shaft is made of large iron pipe with journals of cast steel running in adjustable boxes, allowing the cylinder to be moved up to the saws, to compensate for the wear of the bristles. It is driven by two belts, one at each end. This gives the cylinder the strong steady speed necessary to clean the teeth of the saws well, and cause the gin to mote properly.

The Mason Cotton-Gin is an entirely new departure in cotton-ginning machinery. Its principle is defined as follows: to construct a ginning-cylinder having teeth, which shall seize only the cotton-fibers, and not the seeds or other relatively hard foreign substances contained in the mass presented to its action, and shall strip or remove the cotton-fiber wholly or in great degree from said seeds. By "ginning-cylinder" is meant a cylindrical body for drawing out the cotton-lint from the seed-cotton, to be substituted in place of the aggregation of saws now used in an ordinary gin. This, the inventor says, can be accomplished by means of a cylinder having a hard periphery, in which periphery are numerous openings, and in each of which openings is secured a tooth fixed at one end and extending in said opening in a circumferential direction with reference to the cylinder, provided that the position of the free points or ends of said teeth shall approximate to the circumjacent level or surface of the periphery of cylinder, the said cylinder being rotated so that the teeth shall be presented points forward to the cotton. It is requisite, also, that there shall exist in front of and on each side of the end or point of

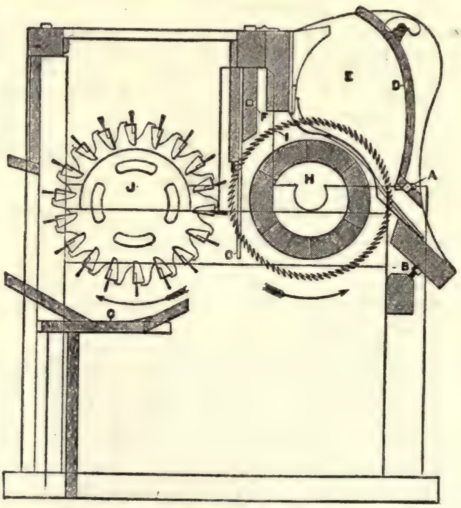


Fig. 2.—Section Eagle gin.

each tooth a space or opening into which the lint, by reason of its softness and elasticity, may enter when the cotton is placed in contact with the surface of the cylinder, and into which space the seeds or hard foreign material, not being soft and elastic, can not enter, and into which the seeds are also prevented from entering by reason of their size. By simply causing the cotton to lie in contact with said cylinder when rotating, with the points of the teeth forward, the lint will by its own elasticity enter the openings around the teeth in a radial direction, toward the axis of cylinder, and will be engaged and drawn out by said teeth, while the hard bodies—such as the seed and foreign matters—will not be so engaged. The point of the tooth is also arranged to protrude beyond the circumjacent parts to such a degree only as that by the rotation of the cylinder it may be thrust for a minute distance into the outer adherent coating of the seed.

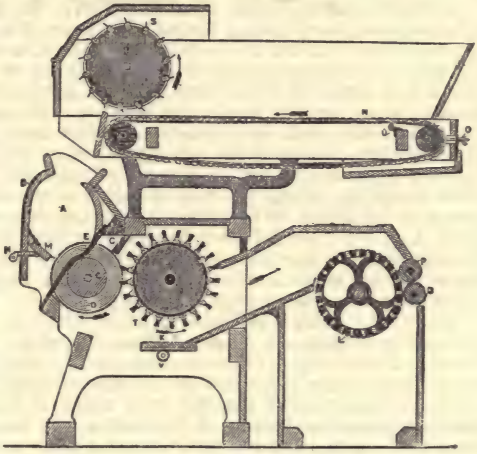


Fig. 3.—Brown gin.

On referring to Fig. 4 it will be seen that this gin uses no ribs or grating. *A* is the grate-fall or breast hinged to the main frame at *a*. *B* is the back-board; *C*, the seed-board; and *D* the brush for removing the lint from the cylinder. *E* is the ginning-cylinder, which in the machine occupies substantially the same position as the saw-gin cylinder in common use, the grate, grid, or ribs being removed, and a bar, *F*, secured in the concave *c*.

The cylinder *E*, shown in detail (Fig. 5), consists of a sheet or thin plate of metal, *G*, preferably steel, which is bent in a cylindrical shape, having its meeting edges secured together around heads or disks, preferably of wood. Said cylinder may consist of a number of smaller cylinders or sections, *M*. The advantage of making the cylinder *E* of a number of sections is, that in case one section becomes injured it can easily be removed and another substituted. The several sections should be placed closely together side by side, and so fastened by any convenient means. Before the sheet *G* is secured upon its support there is formed therein a number of slots *o*, disposed longitudinally across the surface, or in direction of the axis of the cylinder. In each slot is produced a pointed tooth, *g*, lying lengthwise the slot. By reason of the tooth being tapered and pointed and arranged in the slot, there is an open space extending directly in front of the point of the tooth and around the same on both sides. This is the opening already referred to, in which the cotton can enter by its elasticity and softness when pressed against the periphery of the cylinder.

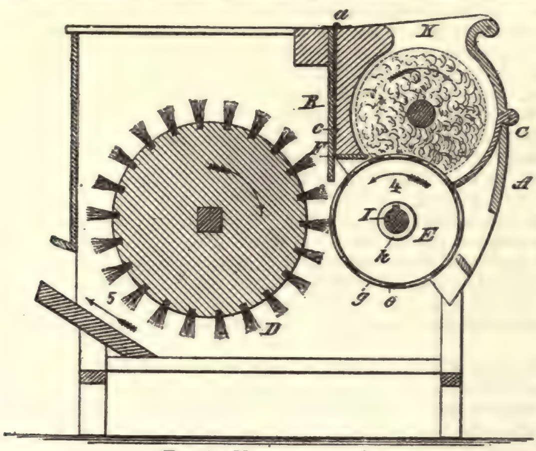


Fig. 4.—Mason cotton-gin.

The openings and teeth in the sheet *G* are made with the sheet flat. When the sheet is bent in cylindrical form, the teeth being attached only on one end will not naturally partake of the curved shape of the bent sheet, but will remain straight, or, in other words, will remain tangential to the circumference. The elevation of the point is, however, so slight as not to enable it to engage with hard foreign substances in the cotton, while on the other hand it is sufficient to allow it to penetrate, as already stated, through the soft covering of the seed before drawing out the fiber, as the rotation of the cylinder continues. Returning now to Fig. 4, the operation of the machine is as follows: The seed-cotton is placed in the receptacle *K* and meets the toothed surface of the cylinder *E*, which rotates in the direction of the arrow 4. The teeth upon said cylinder engage only with

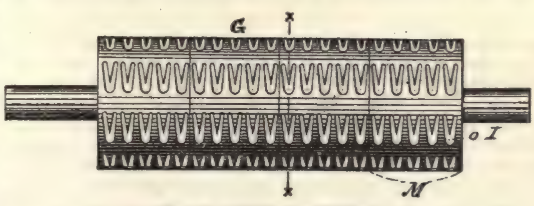


Fig. 5.—Ginning cylinder.

the cotton-lint, as already described, and carry the same past and under the bar F, which prevents seeds and other foreign substances being drawn around the cylinder with the lint. As the cylinder continues its revolution, the lint is removed from its teeth by the brush-wheel D, from which the cleansed material passes out of the machine in the direction of the arrow 5.

COTTON-SPINNING MACHINERY. To show more plainly the advance in cotton-spinning machinery during the past ten years, it may be well first to state in a general way the operations that are at the date of this work in use in converting the cotton in the bale to the warp on the beam, or the filling on the cop or bobbin, ready for weaving. The cotton is received at the mills in compressed bales, containing about 500 lbs. each, and generally confined by ropes or iron bands, and sacking. In this cotton is a very considerable amount of leaf, sand, and seeds, and sometimes other foreign substances. The first operation is the opening of the bales and the mixing of cotton, which is done by hand, so as to secure a comparative evenness of fiber. A number of bales are opened at once, and the mixing is supposed to be thorough. From the heap of cotton so mixed it is taken to an opener, where it is subjected to the action of beaters and fans, and delivered in rolls called laps. Two or more of these laps are then fed to a finishing lapper, where the beating operation is again gone through, and the lap from this machine is the completed product of the picker-room. The cotton at this stage has been freed from the larger portion of the foreign matter, and the fibers have been thoroughly disentangled.

The next operation is that of carding, which is a very important one, and perhaps not yet thoroughly understood. The lap from the picker is slowly fed into the carding-machine, in which is a revolving cylinder covered with clothing, containing teeth, by which the cotton is carried past either stationary or movable surfaces, also containing teeth, and deposited upon another cylinder called a doffer, from which it is taken off in a thin sheet by a comb. The card continues the cleaning of the cotton, and thoroughly disentangles the fibers, and places them in a condition in which they can be easily straightened.

It is stated, in most books of reference, that the cards straighten the fibers; but any one who will examine with a glass the sheet that comes from the doffer will be satisfied that the fibers lie in anything but parallel directions. They are so disposed, however, that straightening becomes an easy process in the drawing to which the fibers are afterward submitted. Where carding is well done, the fibers are thoroughly disentangled, and the sheet is free from lumps, technically called mits. There are two kinds of cards in large use on cotton: the stationary flat card, and the revolving flat cord; the latter being quite generally known as the English flat card, though now manufactured by several American shops. The revolving flat card is said to do the largest quantity of work, but that is asserted by the friends of the other card to be due to the use of larger cylinders. It is also claimed that the revolving card makes less waste. There is no doubt that there is a better feed in use on the revolving flat than on the ordinary card as previously built. Another important point is this: the flats of the common card have to be raised at stated intervals to be cleared from accumulations of dirt and fiber. When they are raised an opening is left, in which the flyings from the cylinder collect, to the detriment of the work when the flat is replaced. With the revolving flat the cylinder is always covered, and the flats not in use are thoroughly brushed out, between their service at the rear side of the cylinder and their next service at the front side. The cotton leaving the card is, with the revolving flat card, gathered together into a strand, and run into a can. Where the ordinary card is used, the strand is fed into what is termed a railway-box, where, with other strands, a sheet is formed, which is carried by a belt to what is termed a railway-head, where it is reduced in size of strand by drawing-rolls, and subjected to the action of an evener.

The next operation is known as drawing, which is done to complete the straightening of the fibers of the cotton and to reduce the sliver, the technical name for the strand in this condition in size. Besides this, the strands are doubled over and over again before being drawn, to equalize the diameters of the resulting strand. The theory is that by doubling, large places in one strand are likely to come opposite small ones in another strand, and the general average of size be improved. Too much drawing, however, weakens the material, and there is considerable question among manufacturers as to the proper amount. Where the English card is used, the cans from the card are set up behind the drawing-frame; and where the railway-head system is used, the cans from the railway-head are placed in that position. The material is delivered from the cans on one side of the frame through the drawing-rolls to cans on the other; the diameter of cans being generally reduced with the diameter of the strands. The process of drawing was the invention of Arkwright, and it consists in subjecting the material to the operation of several pairs of rolls, the front ones of which revolve more rapidly than the rear ones, and thus elongate the sliver and correspondingly reduce it in diameter. From one to three sets of drawing-frames are now in use in most mills. The sliver at the last drawing-frame is made as small as it is sure to hold together in being drawn out of the can. To enable it to be still further reduced, it is necessary to introduce twist in the next processes. Machines by which this is done are called, in general terms, roving-machines, and their product is known as roving. These machines, like the drawing-frame, draw the cotton still smaller, and communicate twist to it by means of revolving spindles with their fliers, and wind it upon bobbins.

Of the two kinds of roving-machines in use, viz., the so-called speeder and the so-called fly-frame, the fly-frame during the last ten years has gained upon the speeder, especially on fine work. The roving, in being prepared for spinning, passes through from two to four of

these machines successively, and at some of them it is doubled, for the purpose before stated in referring to drawing-frames. The final result is a soft cord, having a slight twist in it, and weighing on ordinary work about four skeins, or two miles to the pound. For coarser work it is heavier, and for finer work lighter. This is the last process of the carding-room, which embraces, in all factories, opening, carding, drawing, and roving machinery, and changes the cotton from its crude condition in the bale into fine continuous strands wound upon bobbins ready for spinning. In a mill where cloth is manufactured, roving is divided in its destination, part for warp and part for filling. The warp yarn is spun with much greater twist, because, in the first place, of the extra strength which it requires in weaving; and, second, because the less twist of the filling, gives a soft appearance to the cloth, and is of advantage in dyeing or printing. The warp yarn is spun upon what are known as ring-frames, previously described, which receive the roving from the carding-room, and convert it into yarn of the size desired. The reduction in size is made by drawing-rolls, as before, and twist is given as in the fly-frame, by the rapid revolution of spindles; but, in the winding upon the bobbin, the ring and traveler previously described are substituted for the flier. The ring-frame has been improved during the last ten years more than any other machine used in manufacturing. The details of these improvements will be referred to later.

Following the yarn from the ring-frame, where it is wound upon bobbins, it goes to the spooler, where the yarn is unwound from bobbins and wound upon a large spool holding 20,000 yards, more or less. As each bobbin is wound off, another is tied on, until the spool is full. The yarn in going from the bobbin to the spool is passed through what is called a spooler-guide, which cleans the yarn of many bunches and imperfections, which might better have been taken out in the carding-room, if possible. After spooling comes warping, in which a large frame called a creel is filled with spools, usually 300 or 400 in number. The ends from each of these spools are drawn together into a flat sheet, which is wound upon a beam, usually about 54 in. long and 24 in. in diameter of heads. Each one of these threads passes through an eye, which, with other mechanism, serves as a stop-motion for the machine, so that if one thread breaks it can be replaced, and the sheet of threads kept complete. The full beams are taken to a sizing-machine called a slasher, and there they are run through boiling size and dried upon a cylinder or over steam pipes, and wound upon a loom-beam at the other end of the machine. The threads are then drawn through loom harnesses and reeds, and the warp is ready for weaving.

Filling is spun either upon filling-frames or mules. During the last ten years the filling-frame has been gaining upon the mule on coarse and medium work, and also on fine work where considerable twist can be used, such as thread-yarns. The filling-frame, after spinning its yarn, winds it upon a bobbin, while the mule winds it in what is called a cop, with a paper tube for a base. These bobbins or cops are subjected to the action of heat or dampness to prevent kinking in, drawing off and are then ready for use in the loom-shuttle. Several times as much waste is made in weaving mule or cop filling as in weaving frame or bobbin filling. Some yarn for weaving, and almost all for other purposes, after being spun is doubled and twisted. This requires the use of the machine known as a twister. The twister is a similar machine to the spinning-frame, except that it does not draw the yarn. It takes two threads or more of completed yarn and twists them into one, and winds them upon a bobbin. The twisted yarn, if destined for weaving, is then spooled, warped, and dressed as usual. If destined for other purposes it is subjected to other operations, beyond the scope of this article. Considering the diversified field of manufacture from the cotton-bale to the loom, it is best to classify the different processes.

Opening and Picking.—In openers and pickers the changes are in the nature of improvement in the manner of utilizing old ideas rather than radical innovations. The clearing-trunk is being used in improved forms on openers, and so are automatic feeds and lap-eveners. A preparatory machine, called a bale-breaker, made by Platt Bros., of Oldham, England, breaks the matted cotton into small pieces before it comes to the pickers. This has also a new dust-trunk, through which the cotton is drawn by the exhaust opener. The cotton passes one way by means of a fan-draft while the grids travel slowly in an opposite direction.

Cards.—Although there has been much commotion of late years over this subject, it results rather from the increased use in this country of the English revolving flat card, old in principle but improved in detail, rather than from any important inventions. The adoption of a system in which single carding takes the place of double, and the coiler is substituted for the railway, is enough of a change to excite considerable agitation and discussion. This introduction of English ideas set our shops at work to reproduce and improve on the revolving flat, and also to further perfect the American card, so that it might stand comparison more favorably. No doubt quite a percentage of the improved results of the last few years in carding is due to the use of superior clothing. Tempered steel clothing, needle-pointed, is rapidly gaining ground, and the methods of attachment are better than formerly.

The first American revolving flat card (Fig. 1) was introduced by the Pettee Machine Co., of Newton Upper Falls, Mass. It was constructed after the best English models, and illustrates to advantage the general ideas in use. The Lowell Machine Shop has put an American revolving flat card on the market having several new improvements. The arch is so constructed that the flexible bend is placed close to the cylinder, and its method of setting with the shields prevents all fly from blowing out and packing itself around the bend and chain-blocks. In all revolving flat cards it is highly essential that the cylinder should be capable of perfect adjustment, and also that the flexible bends on which the flats travel may be set so that the flats will be perfectly concentric. As the teeth wear or become ground, this

setting is necessary, and every part of the flat mechanism needs to be perfectly constructed in order that these slight variations may be made. Howard & Bullough have a very ingenious arrangement of conical concentric bends on which the flats rest, which are adjusted in position by screws and inclined surfaces. Each screw has a dial with a pointer, so that by turning each dial a definite distance the bends will all be adjusted alike. They also have a new way of attaching card clothing, using no rivets. Platt Bros., of Oldham, England, have lately adopted a new flexible bend with slots and screw adjustment which admit of the direct setting by the gauge of the flats to the cylinder. They are also so arranged that the flats are ground on the under side while in position.

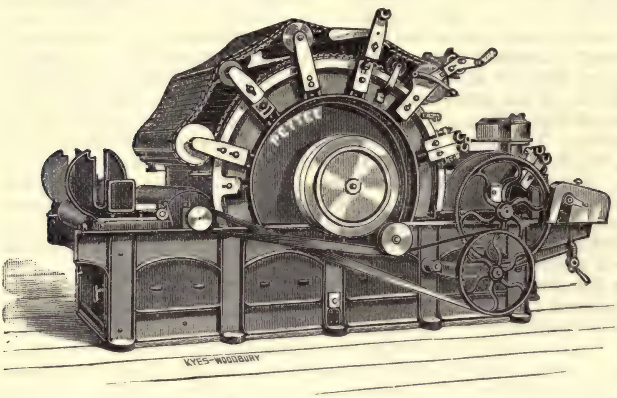


Fig. 1.—Cotton-card.

The Whitin Machine Works have endeavored to so improve the American top flat card as to enable competition in single carding with the English machine. This card (Fig. 2) will produce 100 lbs. and upward per day of fine carding with the minimum amount of waste. The sides and arches of the card are built entirely of iron, and the construction is simple, so that changes can be readily made. The main cylinder is 42 in. and the doffer 18 in. in diameter, measured without the clothing. Both are accurately ground, and are balanced to a speed largely in excess of that used in practice. The cylinder is clothed close up to either edge, securing a carding surface $37\frac{1}{4}$ in. wide. The clothed surface of the doffer is slightly in excess of this. The card is provided with 40 iron flats, the arc described by these being greater than formerly, and equal to fully two fifths of the circumference of the cylinder. The flats are now made $1\frac{3}{8}$ in. wide, with clothed surface of $\frac{13}{16}$ in. They are planed and ground perfectly true to receive the clothing, and, being heavily ribbed are free from the possibility of warping or twisting. The ends of the flat are also planed, and thus their correct pitch with the surface of the cylinder is accurately and uniformly obtained. The device for adjusting the flats consists of a square steel body terminating at either end in a pin. The lower pin, having a fine thread cut upon it, passes through a rib in the card arch, and is secured on both sides of the rib by a nut. Thus any flat may be accurately and quickly adjusted. Mortises, accurately spaced, and planed into a second rib on the card arch, receive the square bodies of the adjusting-pins, thus preventing any lateral motion. The adjusting-pin is further secured by a screw passing through the square body into the arch. The top flat passes over the upper part of the adjusting-pin and finds a true bearing on a small collar turned upon the upper side of the body of the pin. They claim for this device great ease and nicety of adjustment, and perfect immovability when set. A quick stripper, that lifts, strips, and replaces a flat in less than four seconds, is used, and is geared at both sides to avoid torsion. A simple device is attached by which the feed may be instantly stopped, and also the doffer thrown out of gear with coiler and calendar rolls. Many American cards in use are being changed over to the coiler system, the Foss & Pevey cards especially, with better results. The latter card is being improved in addition by the use of the shell-feed.

Combing.—As combers are only used on very fine work, their field is somewhat limited. If some way could be devised to increase the production of a comber with no increase of expense, it might pay to use them to a much greater extent, as the advantage is obvious. Dobson & Barlow, of Bolton, England, have improved the Heilman comber by a change in the combing cylinder (Fig. 3). Formerly the cylinder possessed only one series of combs and one fluted segment. Thus it required one complete revolution of the cylinder to get one length of combed fiber. The manufacturers have succeeded in introducing a second series of combs and a corresponding second fluted section, which doubles production at the same speed; allows of a lower speed, which produces better results, and a largely increased production. The old-fashioned process of preparing comber-laps has been to take slivers from the card, put them through one process of ordinary drawing, and the slivers from the drawing were then put through a small sliver-lap machine and made into a lap for the comber. This old process makes a lap that consists of a series of slivers laid side by side, and is not of one uniform thickness, but first has a thick and then a thin place. It is obvious that the nipper of the comb can not act as well upon this lap as if the thickness were uniform throughout, and further that where the thin places are there is danger of good cotton passing through into waste on account of the defective nip; also, where the thick places come, the pins are required to do too much work, and the quality at once suffers.

When the patent ribbon-lapper is used, the system is as follows: The ordinary style of drawing-frame is thrown out entirely, and the card-slivers are doubled up into a lap directly

on the small sliver-lap machine; then six of these laps are placed in the creel of the machine and are drawn through four lines of rollers in the form of a ribbon instead of a sliver, and by means of curved plates are placed perfectly even and level on a polished table.

Drawing-Frames.—Although the railway-head with evener, first introduced by George Draper & Sons, is hardly the same as a drawing-frame, its functions are near enough like it

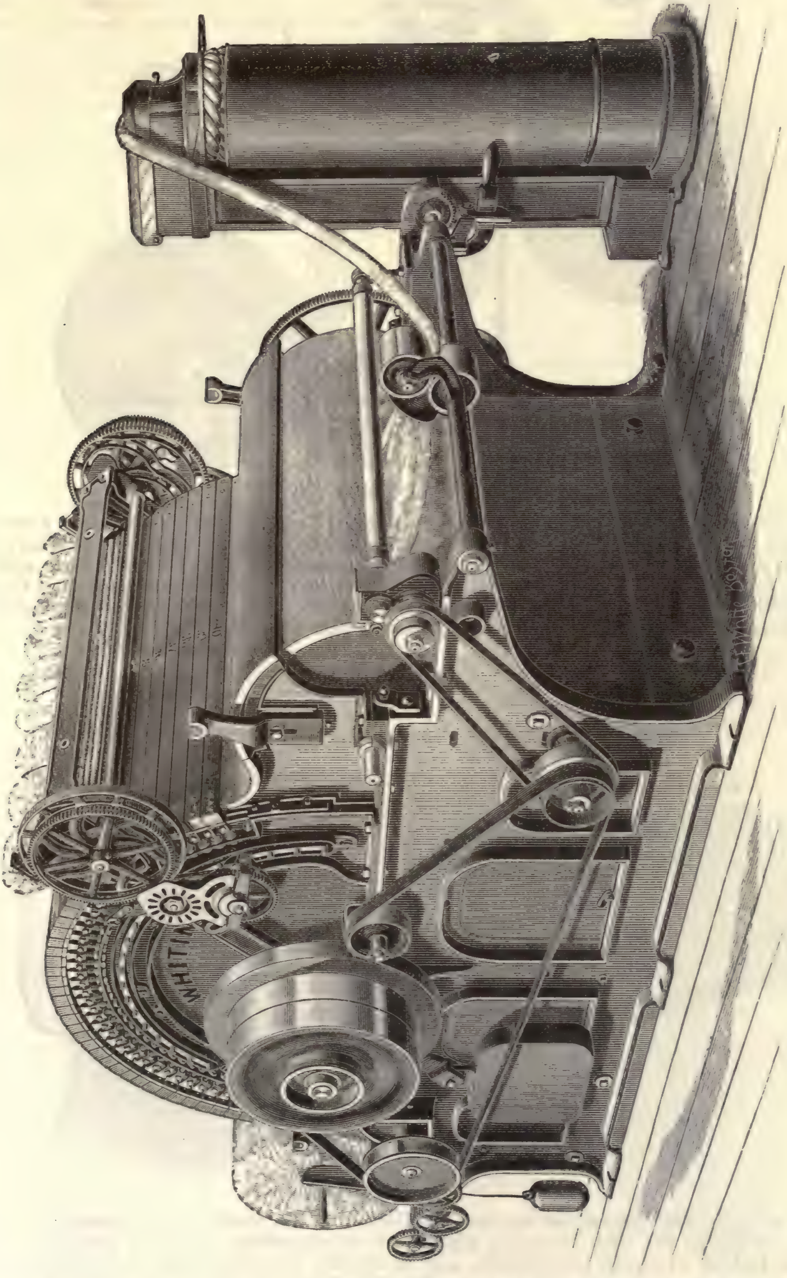


FIG. 2.—Whiting cotton-card.

for it to be considered in the same class. These machines have been perfected and made much more sensitive and accurate. It is of the utmost importance that the evening should commence as soon as possible after the detection of the fault. The Evans Friction Cone Co. have an evener on the market in which two cones with a friction-belt running between them regulate the variations, and are claimed to enable a change of speed far quicker than an ordinary

belt running over cones in the usual way. Railway-heads and machines in the next class have of late been provided with steel fluted rolls, having collars to prevent the teeth meshing too

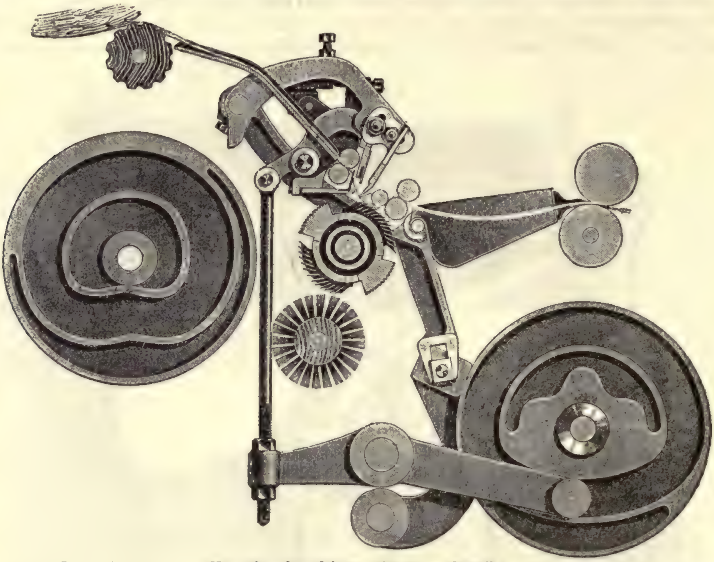


Fig. 3.—Combing-cylinder—detail.

closely, instead of the common leather-covered rolls. They have been pronounced a success in certain instances, but their use is hardly extensive enough as yet to give an opinion as to their advantages. The advantages claimed are less weight required on the saddles, and no expense for roll-covering. This is being introduced by the Metallic Drawing Roll Co., of Springfield, Mass. The drawing-frame, having come into more extended use on account of the addition of the coiler system, is receiving considerable attention.

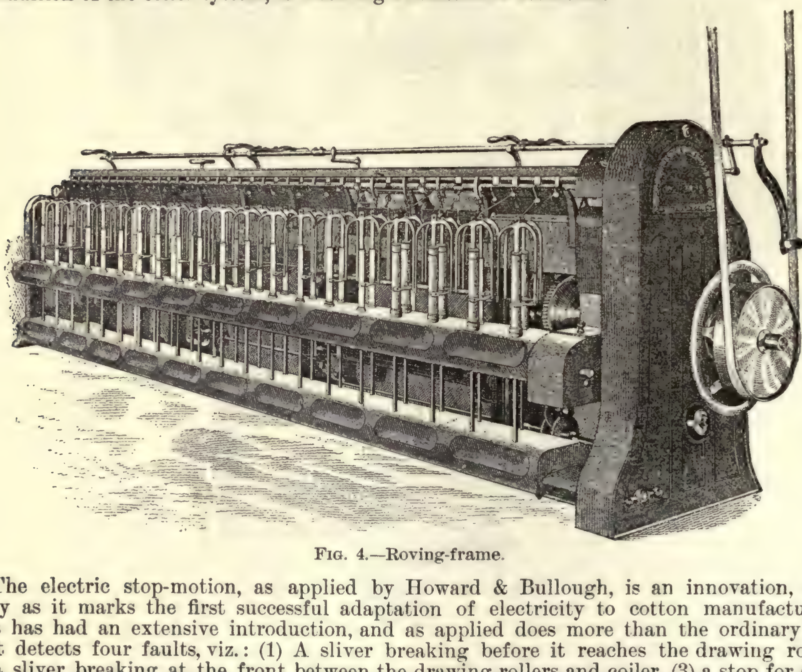


Fig. 4.—Roving-frame.

The electric stop-motion, as applied by Howard & Bullough, is an innovation, especially as it marks the first successful adaptation of electricity to cotton manufacturing. This has had an extensive introduction, and as applied does more than the ordinary stop, as it detects four faults, viz.: (1) A sliver breaking before it reaches the drawing rollers, (2) a sliver breaking at the front between the drawing rollers and coiler, (3) a stop for a full can in the coiler, and (4) a stop when cotton laps around the drawing rollers. Fales & Jenks, of Pawtucket, R. I., are the American builders of this machine.

The Whitin Machine Works are introducing a new drawing-frame with single-bossed rolls, which is an improvement on the general class.

Roving-Frames.—Fly-frames and speeders have undergone considerable general improvement, although much of the machinery now offered to the trade is of the same type and style as that of ten years since. The gradual trend of opinion has turned in favor of fly-frames rather than speeders. Fig. 4 represents the 40-spindle stubble of the Providence Machine Co., of Providence, R. I., and Fig. 5 the Hopedale Machine Co.'s improved roving-frame. In fly-frames one of the improvements is Tweedale's differential motion. In this the revolutions of the various wheels are all in one direction—saving in friction, power, and wear and strain on the cone-strap. Howard & Bullough, besides controlling the above, have applied an electric stop-motion to prevent single breaks necessitating the stopping of the machine. As to the merits of fly-frames and speeders now in use, making four-hank roving or coarser, it is found that the roving can be made cheaper on the speeder and better on the fly-frame. The only reason for the better work of the fly-frame is because the spindle and flier gyrate together when there is gyration, and so the roving is not stretched between the flier and the bobbin, while in the form of speeder now in general use, the spindle and flier being separate, and the spindle and bobbin being sure to gyrate more or less, thin places in the roving must result. The Hopedale Machine Co., of Hopedale, Mass., have made a new speeder which removes this objection.

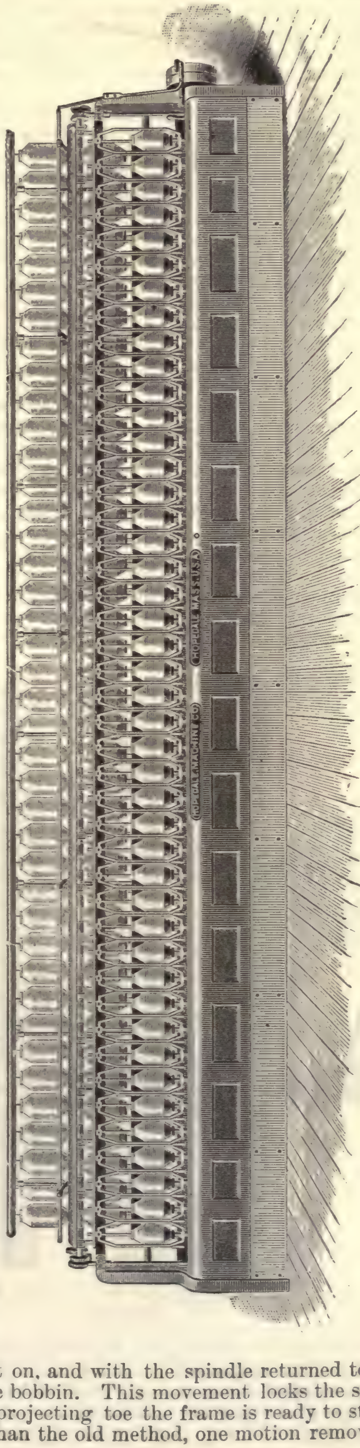


Fig. 5.—Roving-frame.

The common form of spindle in machines of this class is cut off below the top of the bobbin, its support being at the bottom of the flier. This construction limits the speed at which the machine can be run, and even at the ordinary speed the bobbin as it fills shows in many cases a marked variation from true running. The spindles carried to and into the top of the flier, thus making a bearing at both ends of the spindle, and making a much higher speed both possible and practicable, and at the same time improving the quality of the product by avoiding both gyration and vibration of the bobbin, which are so damaging in their effect on the evenness of the roving by straining and stretching it as it follows the movement of the spindle; in other words, because the spindle is held at both top and bottom, it can not gyrate, and the result is even and substantially perfect roving. The lower part of the spindle is tubular, is connected with the driving-gear on the lower shaft, and extends through the base of the flier, where it is provided with lugs to carry the upper part, which is slotted for a sufficient portion of its length to receive and carry the flat or traversing part of the spindle, which rests on the traverse rail and carries the bobbin by a toe which projects from its top outside the slotted part of the spindle into the base of the bobbin. The spindle is solid above the slot, and continues upward through the flier to its nose, where it is held by an ingenious lock. The top section of the spindle, the tubular or lower section, and the flat traversing part can be removed at any time by taking off the bobbin and without disturbing either flier or flier-plate. When the bobbins are full and ready to doff, the frame is stopped with the toe carrying the bobbin projecting from the back or front side of the spindle, and with the traverse rail at its lowest point; the bobbin is raised until it strikes the lock and lifts it, unlocking the spindle and allowing it to tip forward and the bobbin to be removed; the empty bobbin is put on, and with the spindle returned to an upright position, lifting the lock as in removing the bobbin. This movement locks the spindle in place, and with the bobbin set firmly on the projecting toe the frame is ready to start. This operation of doffing requires no more time than the old method, one motion removing

the bobbin and another replacing it. Supporting the spindle at the top prevents vibration and allows the bearings to be made smaller, which reduces the friction and the power required to drive a given number of spindles, besides allowing a much greater speed. The bearings are made as small as is consistent with durability, can be conveniently oiled, and are thoroughly protected from accumulation of dirt. A spindle can not become bound or tight in its bearings, and may be removed and wiped in a moment. The spindle and flier can be oiled when running. From 15 to 30 per cent increase in speed is gained in this frame, with a product which is as much better in quality, so far as evenness is concerned, as it is greater in quantity.

Spinning.—In this department the change in the last ten years has been radical, with greater proportionate results than those obtained in any other class. Spinning is divided into warp and filling, almost all the warp in this country being spun on ring-frames, and the greater proportion of the filling on mules. Taking the frame first as the most modern, the great advance has been in speed, production, saving of power, and less attendance per product. This results almost wholly from the invention of the top spindle by Mr. F. J. Rabbeth, about 1878. The Sawyer had been having an almost uninterrupted sway, as it was such an advance over the old common type in production, saving in power, etc. The Rabbeth, however, has proved as far superior to it as it was, in turn, the superior of its rivals. The name "top spindle" was afterward changed to "self-centering" spindle. Spindles of this type have since come to be known simply as "Rabbeth" spindles, although every spindle with a sleeve-whorl, before the minute differentiation of modern types, was known as a "Rabbeth" spindle both in this country and abroad. The particular features of this so-called "top" spindle were: First, the above-mentioned sleeve-whorl; second, the loose bolster, supported in a tube which held both bolster and step-bearings, and formed an oil-reservoir to lubricate them; third, the elastic packing, ordinarily composed of woolen yarn which surrounded this bolster, shown in the cut at D; fourth, the flat top step on, rather than in, which the rounded bottom of the spindle moved with the bolster; fifth, the snout oil-chamber, which insures a better supply of oil, and keeps the reserve at a higher level than any other form yet tested. This feature had been before embodied in the Rabbeth-Sawyer spindle. The spindle was called the "top," or "self-centering," spindle on the theory that the spindle acted like a top, and found its center of rotation under an unbalanced load. This theory has since been discarded by experts, it now being thought that the advantages of the Rabbeth spindle are derived, first, from the cushioning effect of the loose bearing; and, second, from the additional cushioning effect of the packing interposed between the bolster-bearing and the surrounding case, both taken in connection with a sleeve-whorl surrounding the tube containing the bearings. The spindle does not center itself, but runs out of center with less jar and vibration and heat, and thus is enabled to bear a greatly increased speed, and to run with less power. The Sawyer spindle was limited in speed. With an unbalanced load it would vibrate and gyrate, at more than 7,500 turns per minute, so as to become useless. The Rabbeth spindle, on the contrary, will bear any speed desired, and the limit of production of the frame is transferred from the speed that the spindles will bear to the speed with which operatives can make good piecings of yarn broken in the operation of spinning. From 9,000 to 10,000 revolutions per minute is the speed at which they are customarily run on medium yarns. The power required to drive them at a speed of 9,000 does not exceed the power required to drive the common spindle at a speed of 5,500.

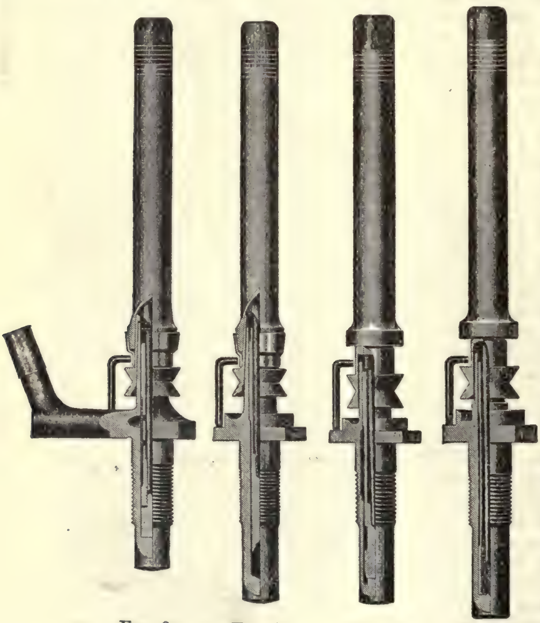


FIG. 6. FIG. 7. FIG. 8. FIG. 9.
Spindles.

Four forms of Rabbeth spindles are being made by American builders at the present time. These are known as the Rabbeth proper, or the No. 49 D Rabbeth (Fig. 6); the Sherman (Fig. 7); the Whitin (Fig. 8); and the McMullan (Fig. 9). They all possess the characteristic features which permit the spindle to be run at high speed; namely, the sleeve-whorl and the supporting tube within it, containing loose bearings, and serving as a reservoir for the oil to lubricate them. The present Rabbeth has many improvements over the original form. The bolster has a head to limit the extent of movement, keeping the spindle in the center of the ring at all times. The spindle proper has been lengthened and made with a tapered bearing. By means of an adjustable screw-step,

the fit in the bolster may be made looser or tighter, taking up wear, and enabling the proper conditions to be found for steadiness. This is the chief improvement in spindles since the introduction of the Rabbeth. The Sherman is a type of Rabbeth having its bolster and step in one piece and using no packing. It has had an extensive introduction. The Whitin is very similar to the Sherman, the main difference being in the fit of the bolster in the supporting tube, the Sherman bolster being loose and the Whitin having supposedly a sliding fit opposite the bolster-bearing. The McMullan has a separate step loose within the bolster, and is the latest spindle on the market. The value of the introduction of these spindles to the community has been enormous. The figures below will show approximately this value, though they are believed to be low, as many incidental gains are not reckoned. The average speed of common spindles, before the invention of the Sawyer, did not exceed 5,500 revolutions per minute. The average speed of the Sawyer spindle may be considered as 7,500, and that of the Rabbeth as 9,000.

The production of yarn is substantially in proportion to the speed of the spindle. It has been found that the increase of production in altered frames was greater rather than less than the increase in speed, owing to the greater steadiness in running. On the basis of the speed, however, 5,000,000 Rabbeth spindles produce as much yarn as would more than 8,000,000 common; 3,000,000 Sawyer spindles produce as much yarn as would 4,000,000 common. It follows that, had the new spihdles not been introduced, more than 4,000,000 additional common spindles would have been required to produce the yarn now spun in this country. The cost of spinning-frames, complete. per spindle, is about $3. It is estimated that a square foot of floor-space is required per spindle to give suitable room for spinning-frames and alleys. This costs, at the lowest estimate, 65 cents per square foot. The necessary plant in and for shafting, heating, lighting, belting, etc., for this room would carry the cost for machinery and room above $4 per spindle. At this figure, therefore, the saving in room, machinery, etc., has been 4,000,000 spindles at $4 each, or $16,000,000. But this is not all. The old spindles, at 5,500 turns, required as much power as the modern spindles, either Sawyer or Rabbeth, at the higher speeds run; hence, the power required to drive these 4,000,000 common spindles may be counted an entire saving At 100 spindles to the horse-power, this would amount to a saving of 40,000 horse-power, or more than three water-powers like that of Lowell, and worth, at $30 per horse-power per annum (surely a low enough price for steam-power in New England), $1,200,000 each year. Then, owing to the better running of these spindles, they require no more attention at their high speed than the common spindles at the low speed. The labor cost for spinning, including all employés, from the spinner to the overseer, is, in the best mills, about a cent and one tenth per spindle per week, or 57 cents a year. The labor saved per annum is therefore above $2,200,000. Then, again, the old-fashioned spindles required oiling twice a day, while the Rabbeth requires oiling only once in three or four weeks, making a saving which would be counted a large benefit were the other items not so enormous.

Capitalizing all these gains at ten times the annual saving. and omitting the minor advantages, the advantage to the community by the introduction of the rapidly running spindles is shown by the following figures:

Saving of machinery	$16,000,000
Saving of power............	12,000,000
Saving of labor............	22,000,000
Making a total of..........	$50,000,000

This is not all. The 3,000,000 Sawyer spindles will all, or nearly all, be changed to Rabbeth, while the remaining common and other inferior types of spindles must also be supplanted by the new types, and the gains from these changes, on the basis above stated, will be in the proportion above shown. Still again, the hundreds of thousands of new spindles per annum required by the growth of the country are substantially all of the Rabbeth type. By making similar calculations to those above, the future value of these inventions to the public may be calculated in the same way.

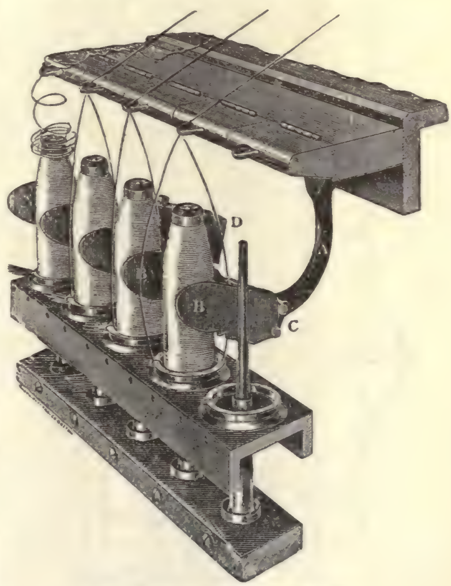


FIG. 10.—Spinning-frame—detail.

So far, we have only considered the advantage for this country. The Rabbeth spindle, in some of its varieties, is the only ring-spindle now built abroad, and it has already gone into use there to the number of several millions. There is no doubt that the advantage to the human race from the invention and introduction of these improvements in spindles has been, from 1871 to date, more than $100,000,000, and that it will go on as their use increases. All the modern spindles now in use are under the control of the Sawyer Spindle Co., whose agents are the firm of George Draper & Sons, Hopedale, Mass.

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The other parts of the frame have also undergone considerable change. It has been found that with the high speeds the yarn is more liable to balloon out and whip together than before, and it has been found necessary to interpose a blade or separator, as it is called, between the spindles to prevent ends breaking from this cause. There are several types on the market, but the original, the "Doyle" (Fig. 10), has received the most extensive introduction, 4,000,000 having been applied. This separator consists of a series of metal blades attached to two rods running parallel with the frame and hinged to supports on the roller-beam. As the ring-rail rises it tips the blades back out of the way, in which position they are also placed for doffing. There are many attachments to these separators to lift them without the ring-rail, to automatically raise them when ready to doff, etc. All the successful separators have the feature of withdrawing when the ring-rail is near the top. The rings now used are the double adjustable type, introduced by George Draper & Sons over twenty years ago. It has been found that by burnishing rings they will start up better and wear out less travelers. The use of hinges on the thread-boards, so that a whole side may be tipped out of the way for doffing by one motion, is being used the last few years universally on new frames. There are numerous designs of lifters and catches, about equally good. In the frames proper, greater care and attention to detail has improved the designs materially. The use of cut-gearing is now insisted upon. The chief difficulty with a frame is to get it perfectly fitted together and set up, so that there will be no cramping and the spindles will come vertical. The Mason Machine Works, in their new frame (Fig. 11), use adjustable legs and cross-bars, which tend to overcome this trouble in the most sensible way. The greatest source of trouble in running a frame is with the banding. Loose bands cause slack-twisted yarn, that makes havoc in the next processes if not discovered, and tight banding consumes power enormously and wears out the spindles. There are numerous tension devices to even the band tension, but the simplest and best way to regulate this evil is by using an invention that is applied to what is known as the Weeks banding-machine, which makes the spindle-bands. The device referred to is a marker which marks all the bands at the proper length, so that when one is put on it may be tied up to the mark, and all will come

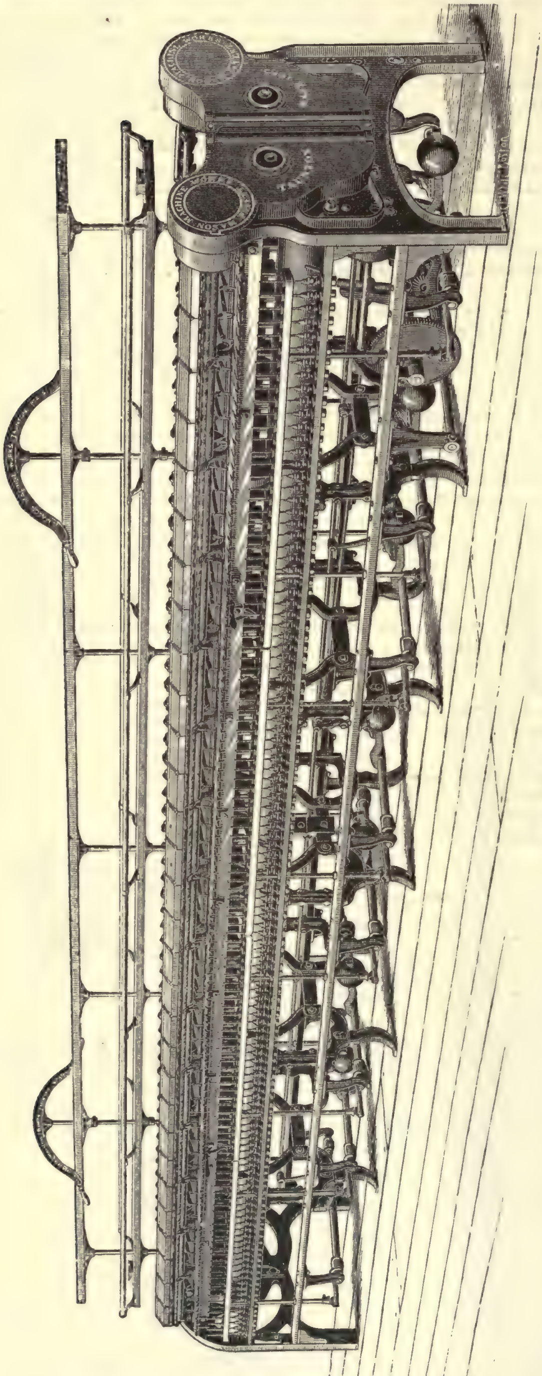


FIG. 11.—Mason spinning-frame.

uniform and correct. An annoyance of some magnitude in the spinning-room is caused by lint accumulating on the lifting-rods, causing them to stick and spoil whole sets of bobbins. The Whitin Machine Co. inclose their rods in a tube, which effectually prevents this difficul-

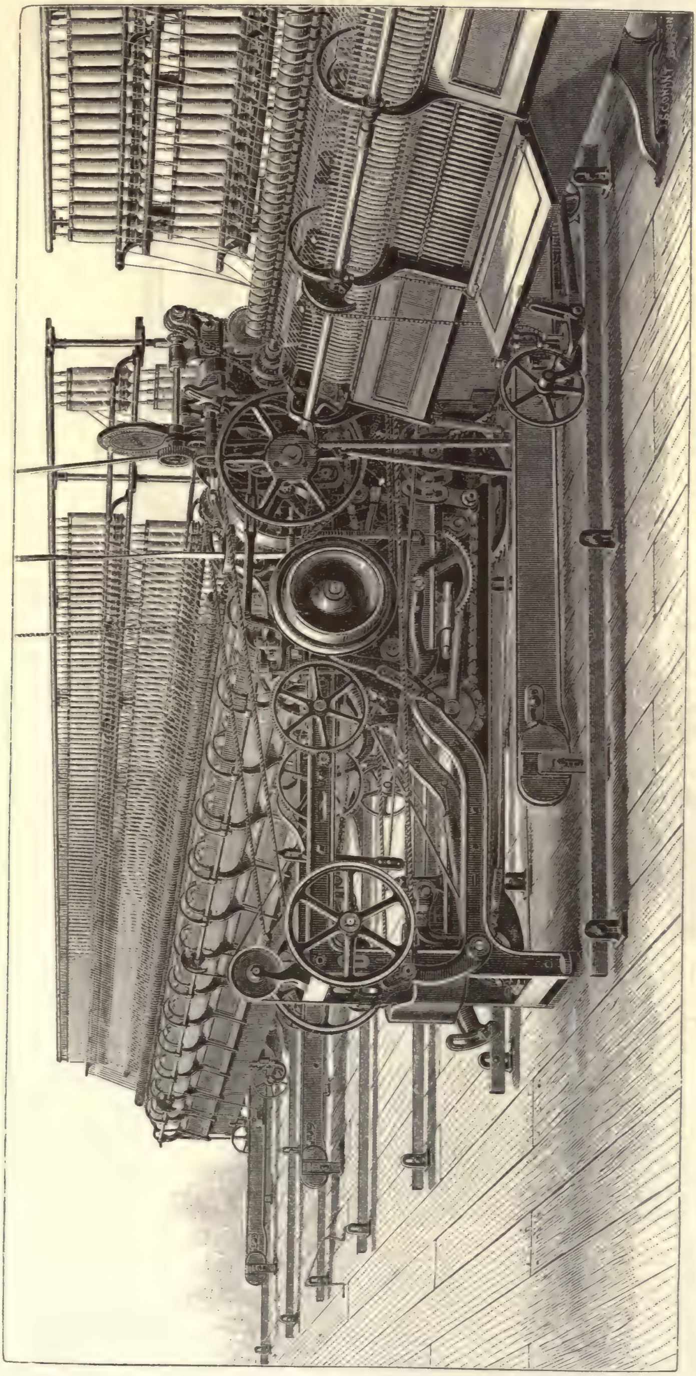


FIG. 12. -Mason mule-jenny.

ty. The Shaw & Flinn lifting-rod cleaner is another device for the same purpose. As has been stated before, the use of the spinning-frame for filling yarn has been increasing rapidly, and while it has not seemed policy to throw out mules before they were worn out in order to

adopt frames, the new mills are to a large extent adopting frame-filling on coarse and medium numbers. The evener of Mr. George Draper, described by us ten years ago, is largely responsible for this change in public opinion, as by the aggressive introduction of this improvement the help have been educated to run filling-frames.

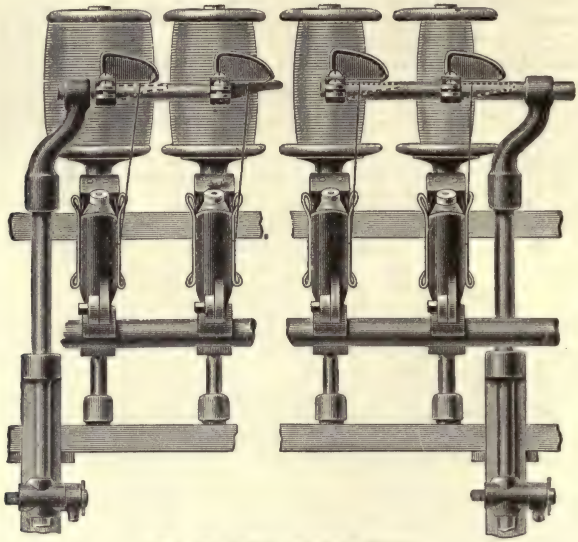


FIG. 13.—Wade spooling-frame.

The great improvements in frames have had their effect by spurring the mule-builders to greater efforts. Mules have undergone considerable change, the advantage gained being higher speed and saving in power. The Mason (Fig. 12) may be taken as the leading American mule, and the late improvements upon it are as follows: An adjustable momentum-brake to check the speed of spindles quickly, instead of allowing it to diminish gradually at the end of every stretch, before the direction of the spindles is reversed for the backing-off operation. By this means a perceptible saving of time is effected at every stretch or draw made by the mule. An improved nosing-motion was also applied to more fully assist the wind-motion to adapt itself to the taper of the spindle, and so prevent the winding on of kinks, when the diminishing diameter of the spindle would otherwise have caused it to fail to take up the yarn sufficiently fast for that purpose. An improved backing-off motion, applied for the purpose of giving a greater range to that particular function of the mule, rendering it possible to back off with equal facility and exactness cops of all sizes and degrees of fineness. A power-doffing motion, to enable the doffing-hands to work the carriage and fallers which guide the yarn, without having to pull the driving-belt by hand, or to leave the front of the mule. A simplified form of chain and chain-gear, for the purpose of drawing the carriage in and out. The flexible spindle-bolster, which rendered possible a much higher speed, and has proved of great value, like the high-speed frame-spindles. A new belt-shifting mechanism, which makes a gain in production of over 5 per cent by extra quickness. The 1890 mule, which is a combination of the best ideas in the English mules, with the improved features of the American, as above noted. The English features copied were the continuous cylinder and faller-rod connections, which runs in one direct line through the whole length. This necessitated a complete transformation in the driving-in and winding mechanism. It will be noticed that in this class of machinery there is plenty of push and improvement. The Lowell Machine Shop also has a new mule for which great saving in power is claimed. Speed and production are equal to the best English mules.

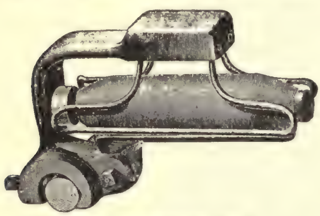


FIG. 14.—Spooler-guide.

The "Parr-Curtis," represented by Messrs. E. A. Leigh & Co., is an excellent representative English mule, and has many new advantages. Its chief feature is the method of driving the drawing-up motion. and the changes, which are worked by a helical spring instead of the cam-shaft, thus dispensing with the latter. The drawing-up and backing-off motion are driven direct by means of an endless band from a grooved pulley, rigid upon the loose pulley of the rim-shaft, the band also passing round a tightening pulley to take up the slack. The speed of the backing-off motion can thus be conveniently altered by changing the grooved pulley without altering the speed of the drawing-up. The American builders of the Parr-Curtis mule are the Saco Water-Power Machine Shop. Other builders have followed the general trend toward more spindles and higher speeds.

Spooling.—An ordinary spooler consists practically of bobbin-holders, guides, and spindles. Although the Wade holder (Fig. 13) is old, it has been improved in detail and mode of application. There are many new spooler-guides on the market, but the Northrop (Fig. 14), introduced by George Draper & Sons, who also introduced the Wade holder, is practically controlling the field at the present day. This guide is adjustable on a round rod, over which the yarn runs, and the slit is adjustable in width for different numbers of yarn. It is extremely simple. Some spoolers are being made with a traveling-belt through the center, to carry away the empty bobbins. George Draper & Sons introduced experimentally a most ingenious idea, consisting in a knot-tyer for each spindle that tied knots automatically. One of the great difficulties in weaving arises from the long ends of these knots tangling the warp. The automatic tyer cut these ends short and avoided this trouble. Drum-spoolers are still used, though in inferior numbers, and have been improved to quite an extent. Stop-motions for

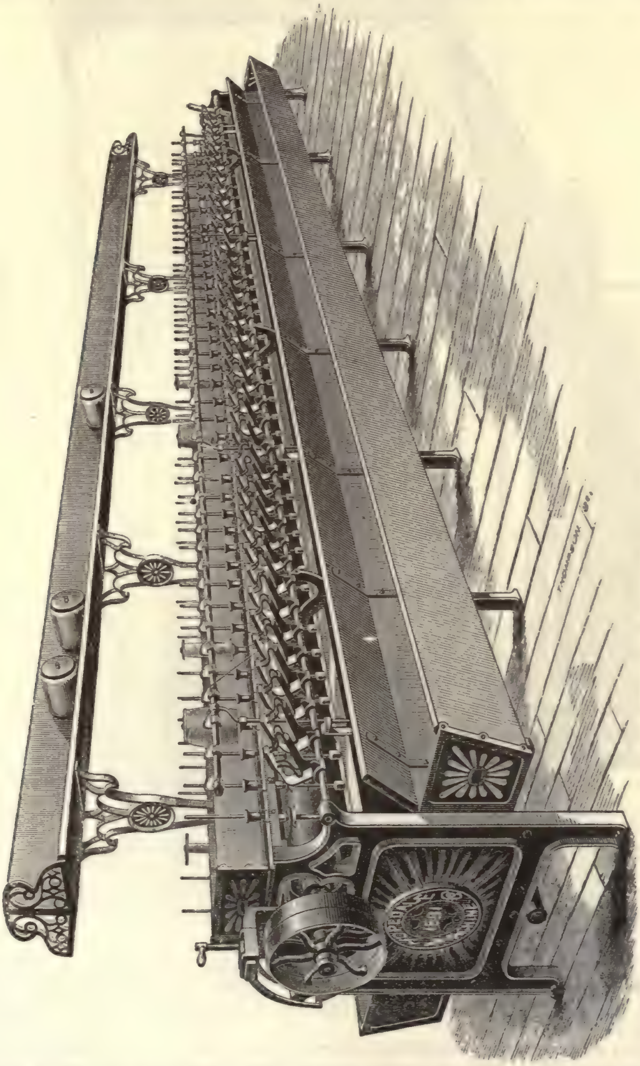


Fig. 15.—Hopedale Machine Co. spooler.

doubling spoolers of many kinds are being experimented with. The Hopedale Machine Co.'s spooler is represented in Fig. 15.

Warping.—The ordinary warper has undergone but little change in the last few years. The rising roll and the Walmsley stop-motion are used more extensively than ever. Improvements in details of creels, combs, etc., are hardly of enough importance to chronicle as embodying new principles. There is, however, a branch of warping that has received considerable attention, and that is the production of chain-warps to be linked or wound on balls. The great change of custom in the processes of dyeing have brought about the use of these machines, the old fashion of dyeing from skeins being entirely changed. The process of chain-

warping, making a chain direct from the spools and linking it automatically, was the first innovation. The Walcott warper came into use for this purpose, and as chains of 1,000 yards were most commonly used, containing from 500 ends upward, it was admirably adapted for the purpose. The Denn warper also was used, especially where 2,000 ends or more were run

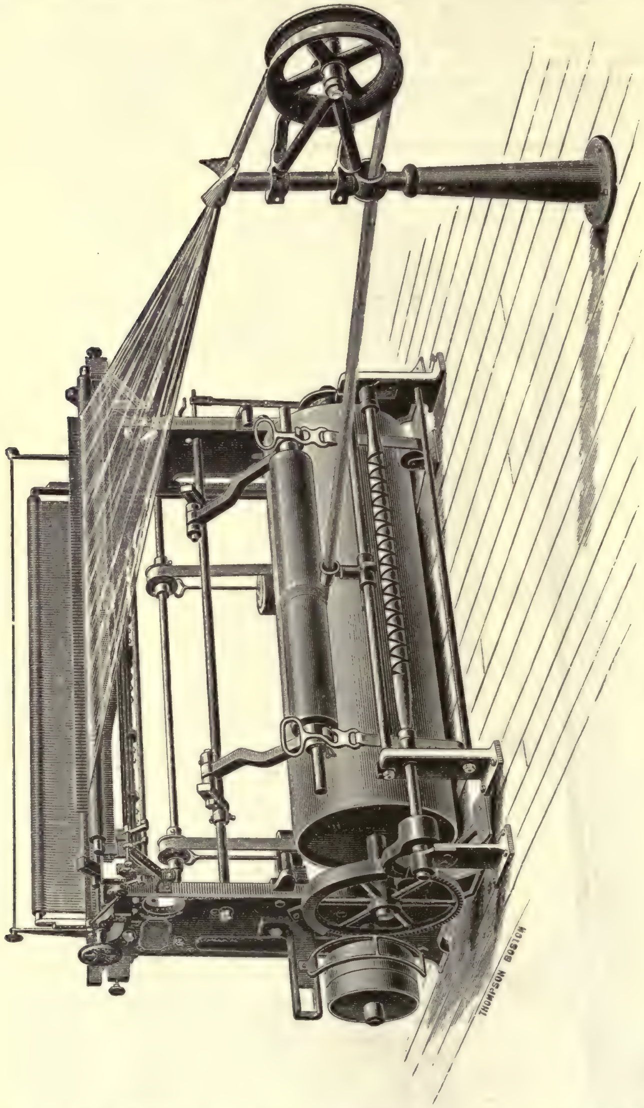


Fig. 16.—The Hopedale warper.

into a chain. Of late, however, the long-chain system is far in advance, on account of the greater cheapness in handling and dyeing. For these the Hopedale warper, with the Straw leasing-motion, and Clarke balling-machine (Fig. 16), is unequaled. In these, long chains from 350 to 500 ends are run.

The operation of this balling-machine is very simple: The ends are taken from spools in a creel through the regular slasher-warper to the front comb, in place of which is a Straw leasing-motion; after passing through this the ends are brought together in the trumpet and carried over the pulley as a chain and back to a trumpet which traverses the length of the ball back and forth, on the same principle as the card-grinder. The chain is carried diagonally round a shaft which forms the center of the ball, and rests against the cylinder of the warper, being held by weight.

Many improvements have been made in this machine since its introduction, and it is now much easier handled and attended.

Twisting.—In twisters the same radical change has taken place as in frames—that is, higher speed, by the introduction of the modern type of spindle. The Sherman form of the

Rabbeth type has been most extensively introduced, and, although they are of necessity much larger and heavier than spinning-spindles, the same principles seem to apply with equally good results. The Hopedale Machine Co. was the first to equip twisters with improved spindles, as they started with the Sawyer. Their machine (Fig. 17) is a good illustration of steady improvement. It is very heavily built and most conveniently arranged for changing twist. Besides the spindles, they are lately introducing a marked improvement, in the form of a stop-motion, the simplicity of which can not but commend itself. Other stop-motions in

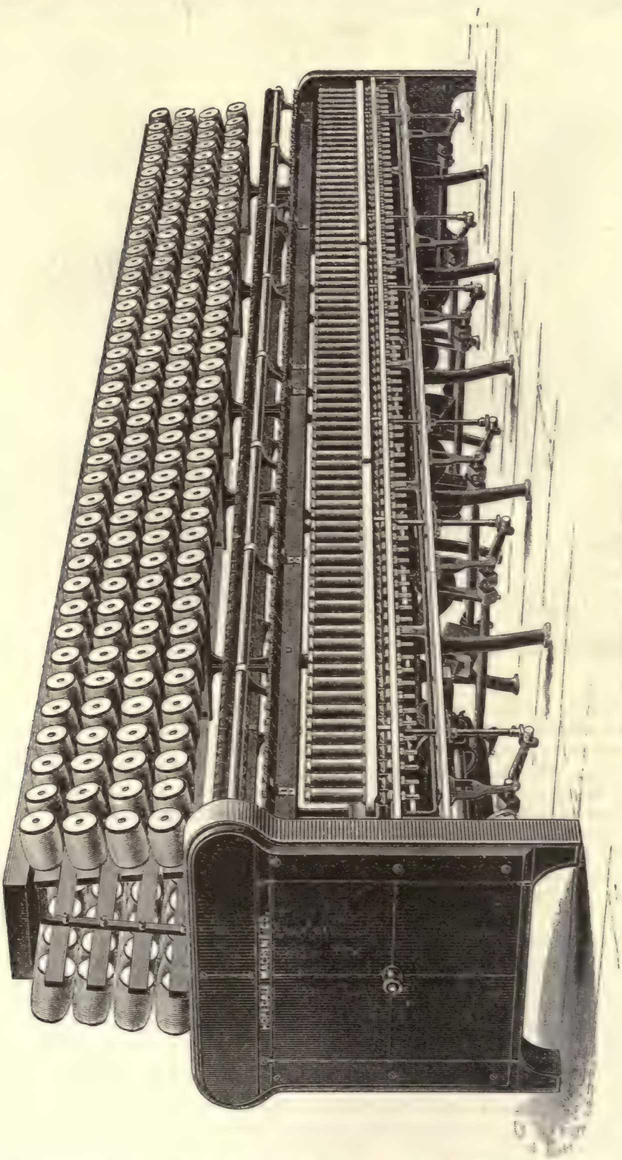


Fig. 17.—Cotton-twisting frames.

use are of such a complicated nature that their introduction has been extremely limited. This one is applied where a single bottom and top roll are used, the top roll having bearings on an inclined track so arranged that if the thread breaks between the spindle and the roll, the roll will run down the track and stop the delivery, preventing roll waste and damage resulting from winding on the lower roll. With two-ply yarn it will act if either strand breaks back of the roll. They also have a new ring-rail for wet twisting, which is made of a strip of rolled brass having flanges so arranged that the rail is reversible.

Reeling, Quilling, etc.—Very little change is noted in reels and quillers of the usual sort, but a new class has arisen, first introduced by Mr. Straw, of the Amoskeag Co., who invented a machine for quilling from a chain. This is used on colored work, and does away with the cus-

tom of reeling and quilling in the old way. The Whitin Machine Co. have introduced a chain-quilling machine (Fig. 18) having novel features. The chain of yarn that comes to the machine from the dry cans is placed on a turn-table and passed over friction-drums the same as in ordinary chain-beaming, and is then wound upon bobbins in this machine. The arrangement of the spindles allows a very compact machine to do a large amount of work. Lapped ends can not

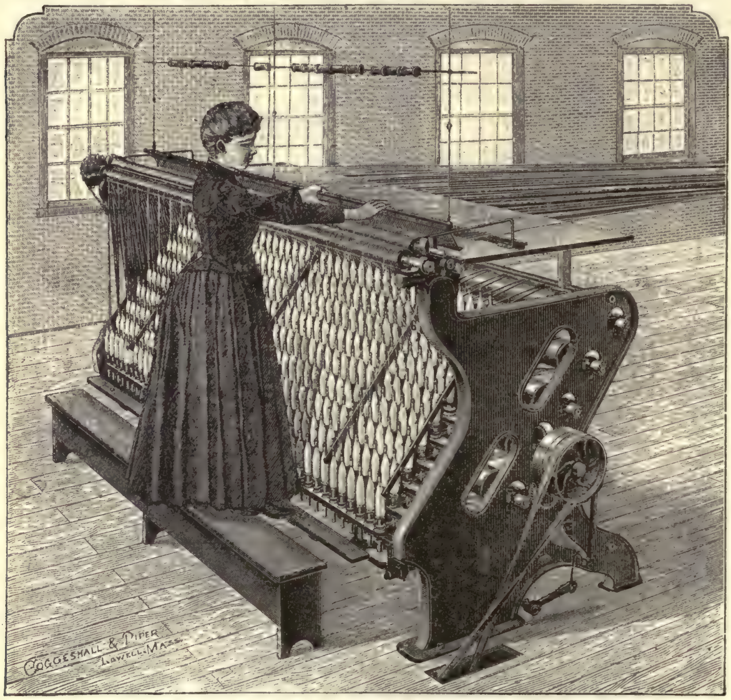


FIG. 18.—Chain-quilling machine.

be made, consequently bobbins will weave from start to finish without break of yarn. There is no friction device, therefore the color is left clean and bright on the yarn—a marked advantage.

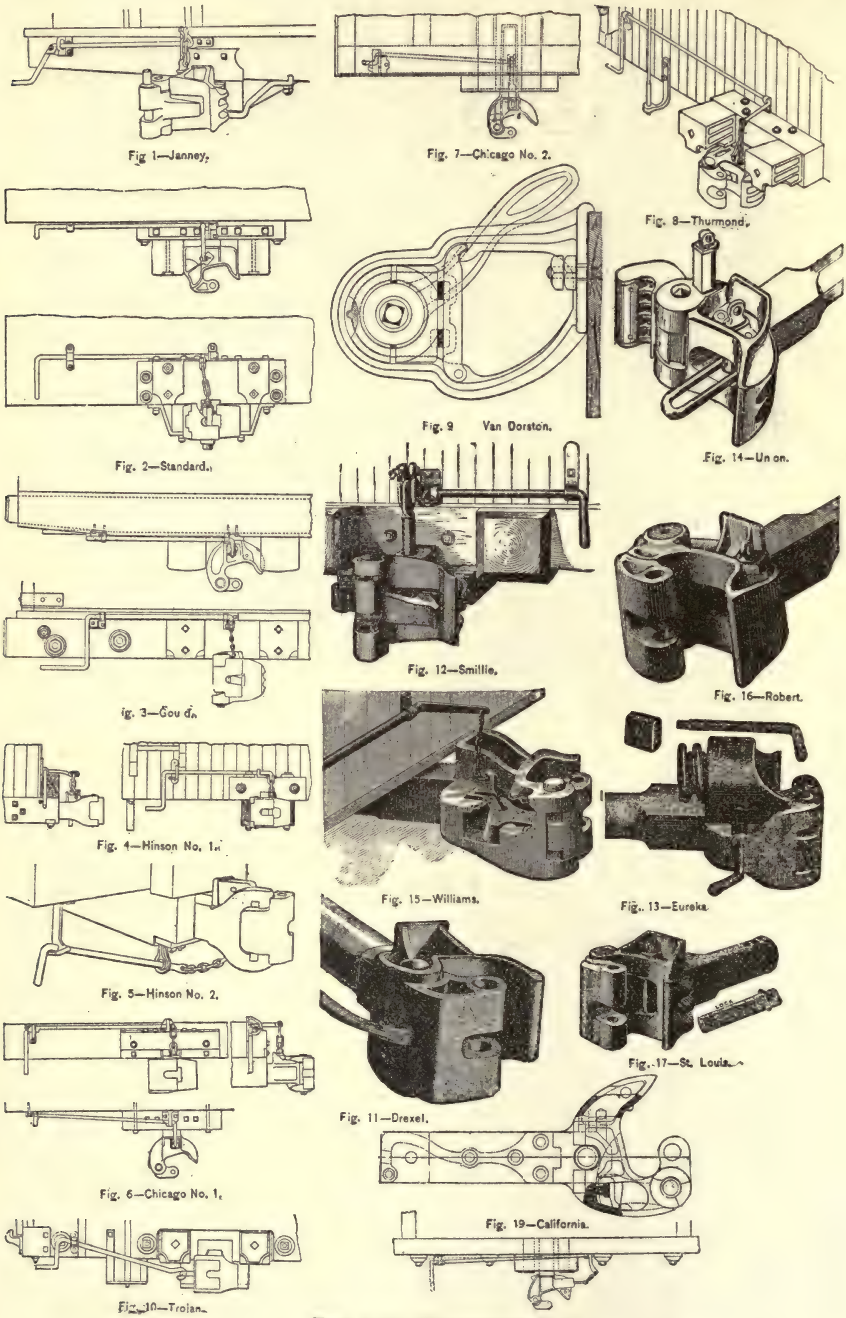
The above practically covers the whole field of ordinary cotton manufacturing up to the process of weaving. Of course, for special instances, special machinery has to be invented, but its interest is of a local character. There is no doubt but that the industry of cotton manufacturing has advanced materially in the last ten years, and more by improved machinery than in any other way.

COUPLERS, CAR. The requirements of an efficient car-coupler are thus summed up by Prof. S. W. Robinson: 1. That they be coupled and uncoupled without requiring men to go between cars. 2. That, whatever the relative heights of the couplers, they couple and uncouple equally well. 3. That free slack, as far as possible, be dispensed with, to reduce damage to equipment and freight. 4. That cars can be coupled easily and with a minimum of concussion, to encourage careful handling of cars. 5. That they be simple and durable, and at a minimum of cost. 6. That the couplings at both ends of a car be alike. 7. That there be no loose parts to be lost. 8. That they couple on curves. 9. That they couple with certainty, and remain so without danger of parting on the road. 10. That they be such as act favorably with brakes. 11. That coupling and uncoupling be unobstructed by inclement weather. 12. That the coupling be universal, or readily connecting with all other couplers. 13. That they do not occupy excessive room in a train, to give it undue length.

As the result of protracted experiments, Prof. Robinson concludes: 1. That the avoidance of "free slack" is one of the most important steps to be taken in the freight-car coupler, and that this is only second in importance to the adoption of such devices as shall be automatic, and not hazardous to the lives of trainmen in operating. 2. That the threefold numerous dimensions to be provided for in the link and pin coupler, as compared with hook-couplers, and with the link and pin, the free slack is greater than in hook-couplers, leading to disastrous consequences, while with hooks it can be reduced to practically nothing. 3. That with hook-couplers the rigging at both ends of a car can be positively identical, with no detachable parts, whereas with the link and pin this is impossible. 4. That close hook-couplers can be much lighter than in those where severe concussions occur, as in the link and pin. 5. That close hook-couplers serve much more favorably than others in connection with all kinds of brakes. Figs. 1 to 19 represent the principal forms of car-couplers in use in the United States, and the following table gives particulars concerning them:

Figure number.	Name of coupler.	Location of lock.	How lock is moved to unlock.	Unlocks from above or below.	How lock is held in unlocked position.	How handle at side of car is rotated to unlock.	Connection between unlocking shaft and lock.	Can or can not be unlocked by a shaft on car, with variable position of lifting-arm and variable step for holding shaft in unlocked position.	REMARKS.
1	Janney No. 1	Left of center †	Lifted	Above	Pushing	Below to right	Chain	Can	As now sold.
	Janney No. 2	" "	"	Below	"	" "	No connection	"	Old style.
2	Standard	Center	"	Above	"	" "	Chain	"	As now sold.
3	Gould	"	"	"	"	" "	"	"	Opens by gravity.
4	Hinson No. 1	"	"	"	"	" "	"	"	Latest form.
5	Hinson No. 2	"	Revolved	Below	"	" "	"	Can not	Old style.
6	Chicago No. 1	Right of center	Lifted	Above	"	" "	"	Can	As now used.
7	Chicago No. 2	" "	"	Below	"	" "	No connection	"	
8	Thurmond	Center	"	Above	"	" "	Chain	"	Has adjustable clevis in chain.
9	Van Dorston	"	Revolved	Below		Top to left	Universal joint	Can not	Now being redesigned.
10	Trojan	At side	"	At side		Below to right	" "	"	Pushed to open knuckle.
11	Drexel	In end of knuckle	Pulled	"		Pulled		"	Now being modified. Pulled to open knuckle.
12	Smillie	Center	Lifted	Above	Pushing	Bottom to left	Clevis	Can	Shaft on right of c. r. instead of left.
13	Eureka	"	Revolved	At side	"	" "	"	"	
14	Union	Left of center	Lifted	Above	"	" "	"	"	
15	Williams	" "	"	"	"	" "	"	"	
16	Robert	Right of center	"	"	"	Bottom to right	Chain	"	Uses several styles.
17	St. Louis	Center	"	"	"	" "	"	"	
18	Buckeye	Right of center	"	Right side	"	" "	"	"	Latest form.
19	California	Left of center	"	Above	"	" "	"	"	

Standard Coupler-Gauge.—This has been adopted by the Executive Committee of the Master Car-Builders' Association, for the purpose of determining whether couplers are near enough to the standard contour established by the Association to insure proper coupling with



Figs. 1-19.—Car-couplers.

one another, in so far as it can be insured by close adherence to the standard contour, and also to establish limits of variation for such of the standard rectilinear measurements of the coupler, only, as will promote the interchangeability of couplers in place upon cars.

The gauge for new couplers, shown in Fig. 20, provides means for gauging the contour

lines, excepting the thickness of the knuckle, at points throughout the whole essential extent of the standard form of contour, and it controls the variation in both directions from the standard.

The gauge for new knuckles, shown in Fig. 21, allows $\frac{1}{16}$ in. variation each way from the standard dimensions of 3 in. Fig. 22 shows the limits of standard rectilinear measurements. The limits shown in the table are proper limits of variation for the standard rectilinear measurements.

	Standard.	Maximum.	Minimum.
A......	2 in.	$2\frac{1}{16}$ in.	$1\frac{15}{16}$ in.
B......	30 "	$30\frac{1}{8}$ "	$29\frac{15}{16}$ "
C......	$21\frac{1}{4}$ "	$21\frac{3}{8}$ "	$21\frac{3}{16}$ "
D......	5 sq. in.	$5\frac{1}{16}$ "	$4\frac{15}{16}$ "

Recent Improvements in Car-Couplers.—Car-couplers are almost invariably automatic. The standard contour is closely followed. Among the more important recent improvements is a change in the location of the link-pin hole on the end of the knuckle, made by moving it toward the interior face about $\frac{1}{4}$ in. This gives a large increase in the thickness of metal between the link-pin and the outside face of the knuckle, and tends to reduce breakage. Another improvement is a movement of the pivot-pin away from the end of the coupler to a sufficient extent to allow a portion of the knuckle to pass outside the pivot-pin lugs. This has two beneficial effects; it strengthens the knuckle considerably, and serves as a protection to the lug. There is an increase in confidence in the use of cast steel for couplers. Knuckles are of three kinds—cast steel, forged steel, and wrought iron. Self-opening knuckles and those that may be opened from the side of the car are prominent. Devices have been introduced for overcoming the necessary differences in the lateral displacement of the ends of cars of different lengths on curves. These are of two sorts: one, for the back of tenders, has the form of a pivoted coupler-head; another, for freight-cars, has a spring on either side of the drawbar, which permits considerable lateral motion, and yet returns the coupler to the center on a straight track.

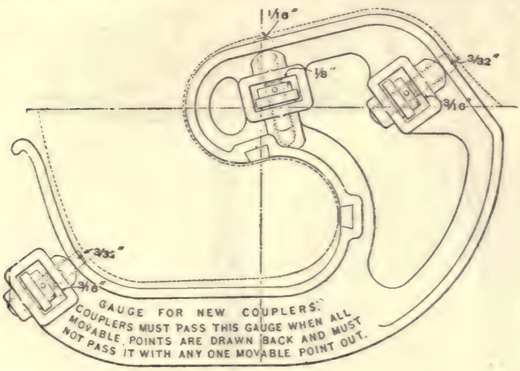


FIG. 20.

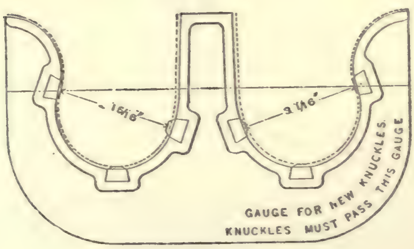


FIG. 21.

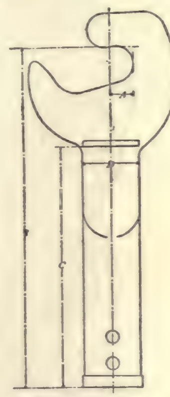


FIG. 22.—Gauge.

(See files of the *Railroad Gazette* and *Proceedings of Master Car-Builders' Association.*)

Couplings: see Carriages and Wagons, Clutches and Couplings, and Fire Appliances.

Covering Boiler: see Boilers, Steam.

CRANES. A variety of improved and novel forms are illustrated.

SWINGING CRANES.—Fig. 1 represents a 30-ton swinging crane, built by Messrs. Sellers & Co., Philadelphia—the peculiar feature of the construction being that anything suspended from the hook can be brought quite close to the center, there being no brace to interfere.

Fig. 2 represents a 40-ton wharf-crane, of English construction, designed chiefly for lifting marine engines and boilers in or out of ships. The engine-cylinders, the position of which is shown on Fig. 3, are 7 in. bore and 10 in. stroke. When the crank-shaft runs at 200 revolutions per min., loads up to 7 tons can be raised at a speed of 13 ft. per min., and heavier loads at 4 ft. per min. The brake has full control of the heaviest loads, and can be worked either by hand-lever or screw. The latter enables the attendant to keep the load suspended for any length of time, without interfering with the engines working for slewing. The slewing is effected by a train of gearing from the crank-shaft, and a pinion on a vertical shaft working into the circular rack fixed on the foundation.

The Great Steel Derrick at the Brooklyn (N. Y.) Navy-Yard is carried on a pontoon 60 ft. wide by 63 ft. long. The tower is built of steel I-beams and rods, and contains 63 tons of metal.

The king post is 65 ft. high; 14 ft. 7 in. from its base it passes through the crown casting. Just above the crown casting the front and back booms are connected to it. The back boom is a box-girder made up of plates and angle irons, and is 2 ft. sq., weighing $6\frac{4}{10}$ tons. The two

FIG. 1.—Sellers 30-ton swinging crane.

members of the front boom are $16\frac{1}{2}$ in. I-beams, spaced far enough apart for the sheaves and tackle to work between. The object of the back boom is simply to afford a point of attachment with advantageous leverage for the back-stays. The upper surface of the members of the main boom has planed upon it sliding-ways for the carriage which supports the sheaves. This carriage bears two lifting-tackles. One is a gantline or single fall, for light work; the other is a 16-fold purchase, for heavy lifting. The hoisting-engine has two cylinders, 8 by 14 in., and by a system of worm gearing and clutches actuates any of the different windlass-drums required. The hoisting-gear alone weighs $13\frac{1}{2}$ tons. The lower main hoisting-block with its 8 sheaves, each 26 in. in diameter, and working on a $2\frac{1}{2}$-in. steel pin, and receiving $1\frac{1}{8}$-in. steel-wire rope, weighs 2,000 lbs. The load-limit is as follows: with the back-stay secured to the after-edge of the pontoon, 75 tons can be lifted; with the sliding-carriage at two thirds the length of the boom and at full-boom length, 50 tons can be lifted; with the back-stay brought into the ball-carriages at the base of the tower, 30 tons can be lifted at two thirds boom length, and 30 tons at full-boom length.

OVERHEAD CRANES.—Fig. 4 represents a 150-ton steam traveling-crane, erected at Woolwich Arsenal, England. It will lift 150 tons on a span of 65 ft. from center to center of the rails. The crab consists of side-frames of steel plates and angles, running upon five double-flanged wheels on each side, securely connected together, and carrying the steam-engine and gearing

for all the movements, with a steam-boiler, coal-bunker, and feed-water tank, the whole covered by a corrugated iron house with angle-iron framing. The cylinders are 10 in. diameter by 10 in. stroke. The speeds provided are as follows: Hoisting, 2 ft. per min. for 150 tons, and 4 ft. and 6 ft. per min. for lighter loads; cross-traverse, 15 ft. per min.; longitudinal traverse, 15 ft. per min. for full load, and 30 ft. per min. for lighter loads. The maximum range of lift is from 3 ft. to 24 ft. from the ground to the bottom of the hook, with the top of the gantry rails 26 ft. above ground, giving a lift of 21 ft. The maximum cross-traverse is 54 ft.

A Novel Form of Overhead Crane, of Belgian construction, is illustrated in plan and side elevation in Fig. 5. It is designed for situations where both light and heavy loads have to be lifted; as, for instance, in foundries, where much time is often lost in hoisting light molding-boxes with slow gear.

Fig. 2.—Wharf-crane.

Upon the two barrels is wound a steel rope with a snatch-block suspended in the bight between the two barrels. The smaller barrel is rotated directly by a chain-wheel and dependent chain. By it one man can lift 440 lb. The large barrel is provided with double purchase-gear, so proportioned that two men can lift a ton. Further, upon the shaft of the large barrel is a coupling, and when this is put into gear both barrels are coupled together by means of a pitch-chain,

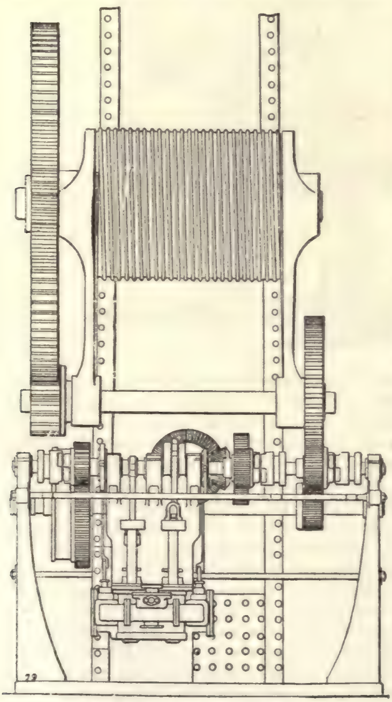


Fig. 3.—Wharf-crane plan.

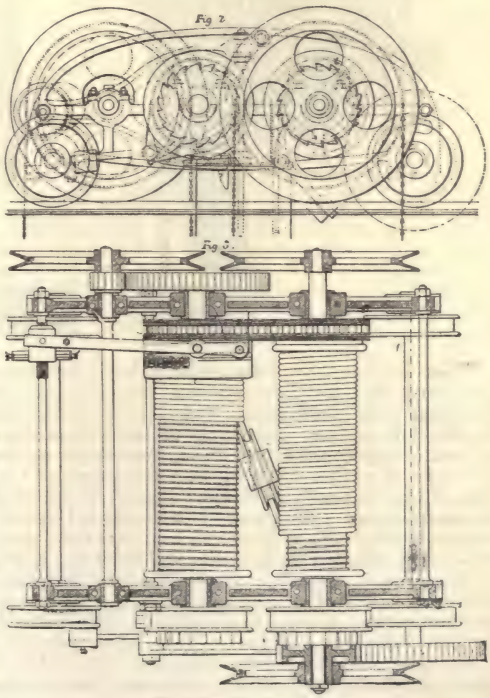


Fig. 5.—Overhead crane.

and a differential raising or lowering action results, by which two men are able to hoist a load of 5 tons. When the two barrels are coupled together, the pawl must be lifted out of the ratchet-wheel of the small barrel.

When a workman has to lift a small weight, he pulls the chain of the small barrel. If he finds the load too heavy, he applies himself to the second chain, without any coupling or uncoupling being necessary. It is only in the case of very heavy loads that any adjustment of the mechanism is required. All the motions can be worked from below by hand-chains.

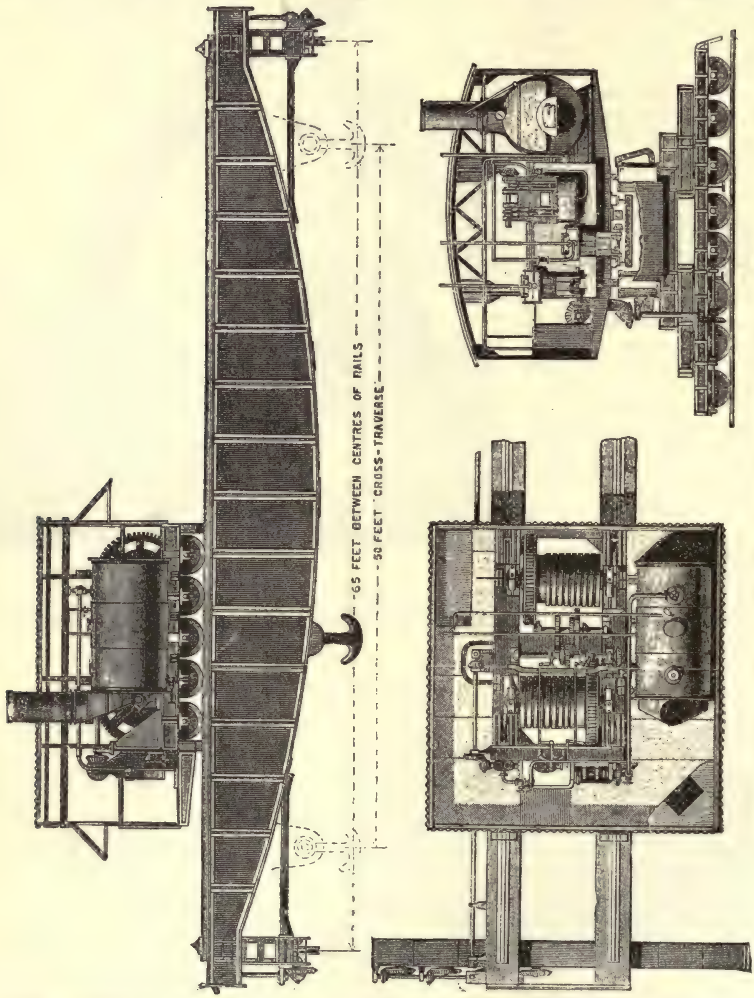


Fig. 4.—Overhead traveling-crane.

Electric Traveling-Cranes.—Electrically driven traveling-cranes have come into extensive use during the past three or four years, the convenience of transmitting power by a wire, as compared with transmission by square shafts, belting, or ropes, being its chief recommendation for this service. Any form of traveling-crane may be converted into an electric crane without changing either the track, the bridge, or the trolley, simply by substituting for the belt, rope, or square shaft, which gives motion to the first rotating shaft, whence all the motions of longitudinal and vertical transverse travel are derived, an electric motor with suitable spurgearing. Preference is now given, however, to cranes fitted with three independent motors, one for each of the three motions of the crane. All the movements are controlled by switches handled by the operator stationed in a carriage at one end of the bridge.

Rope-Driven Traveling-Crane (Figs. 6 and 7) illustrate a rope-driven traveling-crane made by the Philadelphia Engineering Works. In this crane ropes and belts are used as far as possible, instead of gears and shafting. The trolley has the full traverse motion of the bridge. The power is applied by two endless cotton ropes (5, 5) extending along the full length of the shop, being guided by pulley-wheels at intervals. These ropes are kept taut on one end by passing over a movable sheave suspended upon guide-bars, and pass over driving-sheaves (6, 7) placed zigzag in relation to a pair of guide-sheaves, upon either side of the main girders (1, 1).

By this arrangement a long grip on the driving-sheaves is obtained. One of these driving-sheaves (6) is fitted to a shaft, working in adjustable bearings, and carrying three pulleys for the lifting-gear. The power is transmitted from these pulleys, through belts, to a counter-shaft (13) fitted up with three sets of tight and loose pulleys, thereby obtaining

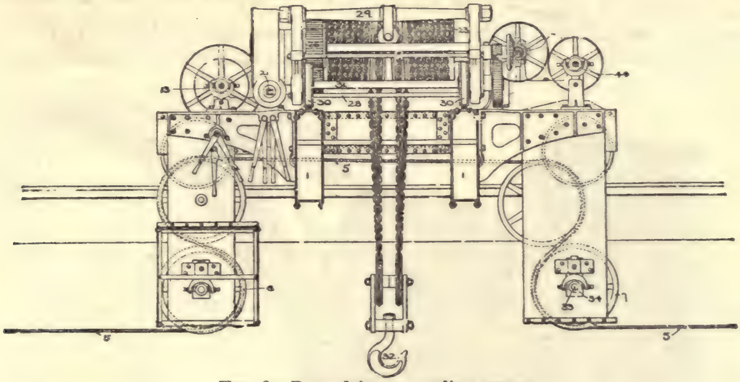


FIG. 6.—Rope-driven traveling-crane.

three lifting and three lowering speeds. From this counter-shaft (13) the motion is transmitted, through a pair of spur-gears, to a square shaft (21) (provided with tumbling bearings), extending the full length of the bridge (1). The motion is then transmitted to the lifting-drum (23), from any part of the square shaft (21), by means of tangent gear (24 and 25) carefully cut by special machinery, and spur-gears (26, 27). The sides of the trolley (28) are made of cast iron, secured to each other by distance bolts and bars (28, 29). The drum (23) is made of cast iron, and has a right and left handed groove for the chains. By this arrangement the load always hangs in the center, between the girders. A driving-sheave (7) is fitted to a shaft (33) working in adjustable ball-bearings (34), and carrying four pulleys, two for giving motion to the bridge (1) up and down the shop, and two for giving transverse motion to the trolley. The power is transmitted from two of these pulleys (one being smaller than the other), through belts, to a square shaft extending the full length of the bridge (1), with two sets of tight and loose pulleys. The power is transmitted from this square shaft to the trolley-wheel through bevel and spur gear-wheels, thereby obtaining two speeds for the trolley travel. The other two pulleys (one being smaller or larger than the other) are belted to two sets of tight and loose pulleys, working on a round shaft (44), and extending the full length of the bridge. The power is transmitted to the bridge girder-wheels on both sides from this shaft (44) by means of compounded gear-wheels, thereby obtaining two speeds for the bridge, and insuring a parallel motion for the same.

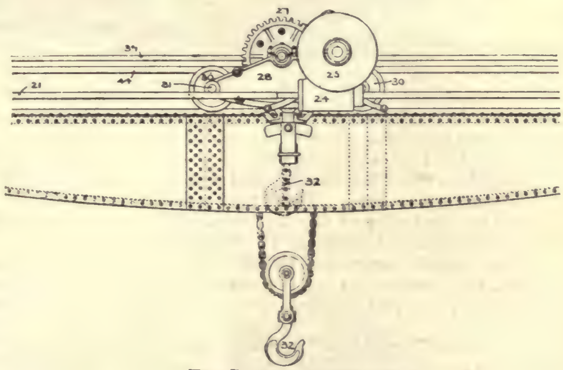


FIG. 7.—Rope-driven crane.

HYDRAULIC CRANES.—*The Ridgway Steam Hydraulic Crane* has a jib carrying a free trolley, which is suspended by short and very heavy chains passing over wheels on the inclined brace and mast, and are attached to the upper end of a cylinder. The piston-rod of this cylinder is hollow, and is bolted to a projection from the bottom gudgeon. This large and heavy cylinder is used to counterbalance the weight of the jib. Conveniently located on or in the ground is a closed cylinder. On top of this cylinder is a plain slide-valve, from which one pipe is run to the boiler for steam, and another outside the building for exhaust. From the bottom of this cylinder a pipe is carried to the crane bed-plate connecting with the passage to the lifting cylinder. The ground cylinder is filled with water to within a foot of the top—air occupying this space. It being now desired to lift the crane, steam is admitted, and being prevented by the air from coming in contact with the water, it does not condense; the water takes the same pressure as the steam, passes to the crane, where, entering the lifting-cylinder, the latter is pressed down the rod, raising the jib and its attached load. To lower, the steam is exhausted and the water flows back by gravity, and the cylinder rises and the jib is lowered.

A hydraulic traveling-crane, designed by Erwin Graves, of Camden, N. J., is described in vol. xii *Trans. A. S. M. E.*

LOCOMOTIVE TRAVELING-CRANE.—A form of crane recently adopted for steel-works, arsenals, etc., for very heavy lifting, has a locomotive boiler and engine on one end of the traveling-bridge, the engine furnishing motive-power through the necessary spur-gearing for the three motions of the crane. This kind of crane is independent of all other motive-power of the works in which it is used, and requires merely to be supplied with fuel and water at some convenient point in its course.

A Locomotive-Crane, of English manufacture, is represented in Fig. 8. It is intended to lift 10 tons at a radius of 20 ft., and 7 tons at a distance of 25 ft. from the central pillar of

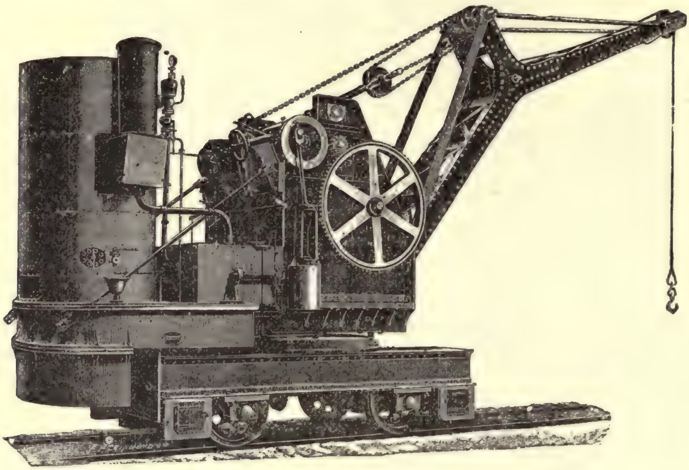


FIG. 8.—Locomotive crane.

the crane, being fitted with a motion which allows this radius to be varied. The hoisting is done by a galvanized steel-wire rope, $1\frac{1}{8}$ in. in diameter, which is wound on a specially large steel barrel. This barrel is worked by double-purchase spur-gearing, the motion of which is controlled by clutches in the usual way. A powerful friction-brake is supplied for holding and lowering the load. The crane has a revolving motion, consisting of an internal bevel secured to the frame of the machine, and a pinion gearing into it, the motion of which can be reversed without stopping or reversing the engines.

The crane is propelled by the same engines by means of which its other motions are worked, the connection to the wheels being made by bevel gearing. These engines have cylinders $8\frac{1}{2}$ in. in diameter, with a 12-in. stroke, and are fitted with a link-reversing motion.

A 40-Ton Traveling-Crane.—The remarkable crane represented in Fig. 9 (called a steam Titan) was built for lifting blocks of concrete weighing 32 tons, used in the construction of the Madras Breakwater. The weight of the Titan, without water-ballast or load, is 152 tons, and with ballast 170 tons. All the motions of the appliance are under perfect control by means of a set of levers situated on a platform, and within easy reach of the single operator. A feature of importance in connection with this appliance is that it not only has to be capable of slewing round in a complete circle, but has also, owing to the shape of the breakwater on which it will be employed, to be capable of traveling on a curved road. To enable it to accomplish this, the Titan is carried upon twelve wheels arranged as two four-wheeled bogies, one at each end, and with driving-wheels in the center. This arrangement enables the Titan to travel with ease round a curve of 90 ft. radius. The radius described by the arm is 50 ft., and to minimize the shock produced by stopping a load, owing to the momentum acquired when being slewed round, spring-braking devices are introduced in connection with the gearing, so as to bring the arm to a gradual stop.

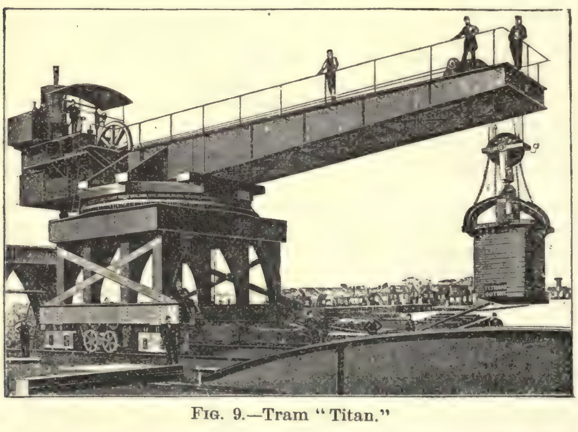


FIG. 9.—Tram "Titan."

Crank: see Engines, Steam.

CREAMERS. This term is applied to centrifugal extractors when used for the separation of cream from milk. Similar apparatus is also employed for the separation of fusel-oil from alcoholic liquors. When a liquid is to be separated from a liquid, the receptacle must be imperforate. The components of different specific gravity become arranged in distinct concentric cylindrical strata in the basket, and must be conducted away separately. In creamers the particles of cream must not be broken or subjected to any concussion, as partial churning is caused, and the cream will, in consequence, sour more rapidly.

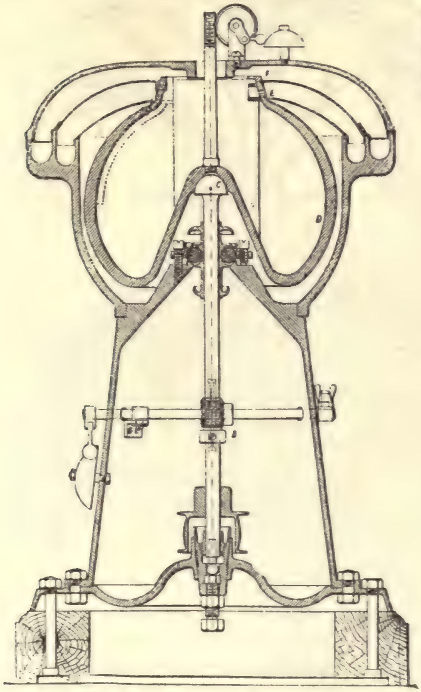


FIG. 1.—Alexandra creamer.

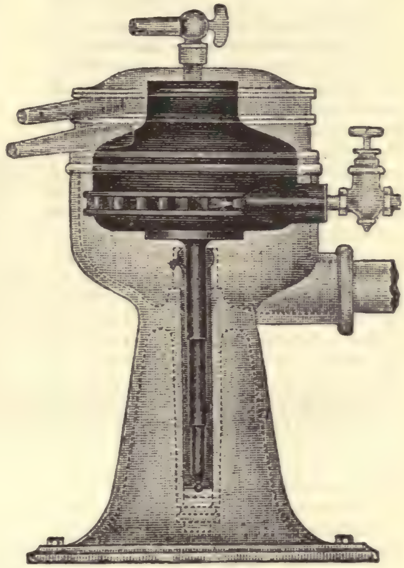


FIG. 3.—Creamer.

The Alexandra Creamer, illustrated in Fig. 1, is one of the most approved forms of English creamer. It is exceedingly light to drive, a result attained by the use of a peculiar form of rotating vessel, which is free to adjust itself on the spindle. This vessel *D* is nearly globular, and has a deep projection in its bottom, much like that which is found in wine-bottles, particularly champagne-bottles. The head of the spindle *C*, which is ball-shaped, fits into a socket formed in this recess. The center of gravity of the vessel is below the point of support, and thus the whole rides easily without any rigid connection between the vessel and the spindle. There is sufficient frictional resistance between the two to impart motion to the vessel without slip, but, if an accident should occur to the driving-gear, the vessel can slip, and thus its momentum can expend itself gradually without adding to the severity of the accident.

This machine under test gave the following results: Quantity of milk, 81·01 lbs. (7·86 gals.); time of skimming, 24 hrs. 15 min.; rate per hour, 19·47 gals.; revolutions of

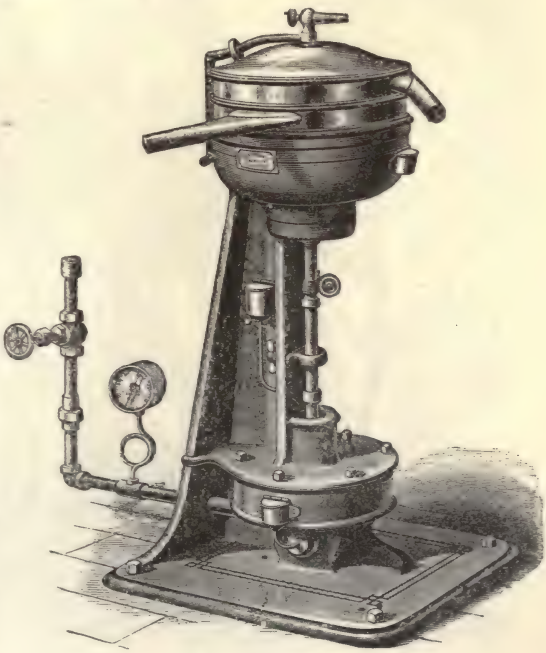


FIG. 2.—De Laval creamer.

handle per min., 45; horse-power consumed, 0·880; units of power per lb. of milk skimmed, 788·1 foot-pounds: temperature of milk, 84° to 87° F.; per cent of fat, 3·25; temperature of separated milk, 79° to 81° F.; per cent of fat, 0·45.

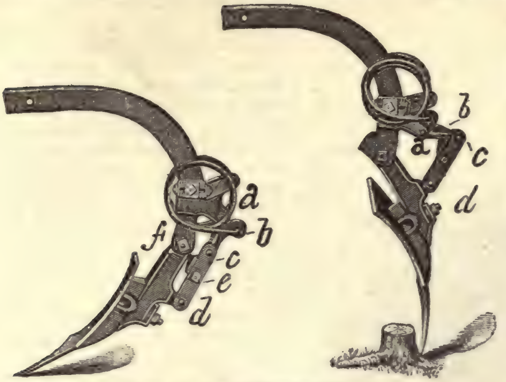
Two interesting forms of creamers are illustrated in Figs. 2 and 3. The De Laval machine (Fig. 2) is driven by a steam turbine, situated in the lower casing. The wheel of the Sharpless Russian machine is located in proximity to the apparatus proper.

CULTIVATORS. The superiority of surface-cultivation for corn has received slow but sure recognition. The large, deeply penetrating cultivator-blades formerly used are disappearing, and the leading manufacturers are producing new cultivators with small teeth in increased number. Fig. 1, showing a corn-plant with its roots, explains the advantages of surface-cultivation with five small teeth compared with the two large cultivator-shovels, in general demand till a recent date. The long shovels cut off the roots which nourish the growth of the ear, and act as guys to sustain the stalk erect, as the long shovels must run deep to cover the ground. If running shallow, long, large shovel-teeth merely make V-shaped scratches, neither killing the weeds nor thoroughly opening up the hard surface. The five small teeth uproot the weeds and leave no part of the surface-dirt undisturbed, yet do not seriously interfere with the tender extended side-roots of the corn-plant. To throw weeds to the surface, where they will die, instead of covering them over, as

FIG. 1.—Corn-plant and cultivator.

FIG. 2.—Albion cultivator.

a rigid tooth inclines to do, as well as to insure clearance and scouring in sticky prairie soils, the combination of the narrow shovel or tooth with a spring-shank has been effected in the Albion Cultivator, seen in Fig. 2. The machine can be adjusted to cut deep when the corn is small, pulverizing the ground well down below the surface; but afterward, as the root-laterals spread out near the surface, can be run shallow above them and still mellow the packed surface and work out weeds. The figure shows the machine fitted with a rider's seat, and also displays the effect of the numerous small shovels. The hill-shields here seen protect from injury the leaves of the plant when well grown, as the machine passes astride the row. After a season's cultivating by this means a field is fairly well rid of weeds, as all weeds that have sprouted successively will have been torn out and left to die. The springing action of the steel shanks tends to shake off dead corn-stalks and trash, as well as to throw out the weeds on the surface to wilt.



Figs. 3. 4.—Cultivator shovel.

Fig. 5.—Bradley cultivator.

Spring-Trip Cultivator-Shovel.—A form of rigidly acting but safety-spring-trip cultivator shovel (Fig. 3) is made by the Weir Plow Co. Fig. 4 shows its tripping feature,

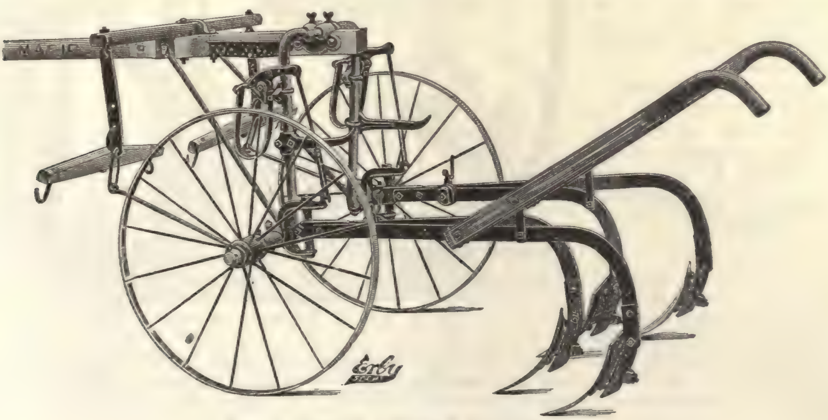


Fig. 6.—Bradley expansion arch cultivator.

by which it passes obstructions without the risk of breakage. The pivots *a c* and *d* are normally nearly in line, allowing the strong spiral springs to offer a very stout resistance to the flexion of the pivot *c*; but when the limit of that resistance is once exceeded by collision of the shovel-point with an earth-fast obstruction, a slight flexion of the pivot *f* causes collision of the nuption *e* with the rear shoulder of *f* by reason of shortening the distance slightly between the center of the pivot *d* and the shoulder, throwing the pivot *c* back out of line with *a* and *d*, raising the point of attachment of the extremity of the spring at *b* enough to nearly neutralize the power of the spring, and thus permitting the point of the shovel to yield backward and draw over any low obstacle, after which the tendency of the spring to uncoil returns the shovel to working position and relocks it. The nuption *e*, termed a break-pin, is adjustable, to change the amount of resistance necessary to unlock the toggle *a c d*, but the pivots *a c d* must never be adjusted in exact line, for in that position there will be no tripping, and the device will continue rigid.

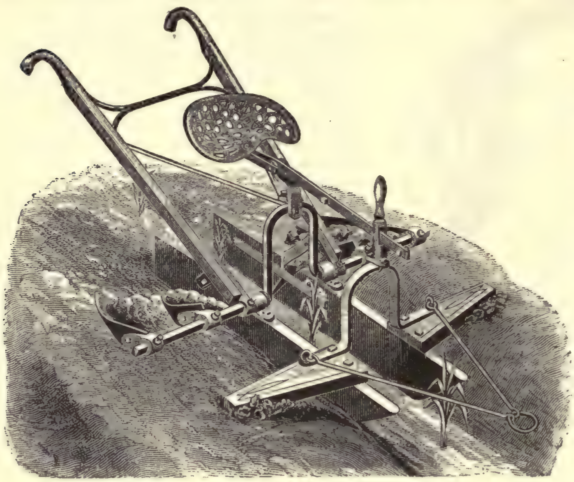


FIG. 7.—Double-blade cultivator.

The Bradley Cultivator Attachment shown in Fig. 5 with narrow paring-blades or scrapers for cutting off weeds or grass below the earth surface and pulverizing the top soil, interchangeable with the ordinary cultivator shovel-blades on the same machine. Fig. 6 shows Bradley's expansion arch, made in two independent parts, passing through and held in a casting on top of the tongue-butt adjustably for widening or narrowing the distance between the two shovel-gangs, which may thus be run close to the plant in early cultivation and farther from it afterward, while always maintaining the straight position of the shovels.

Double-Blade Cultivators.—Fig. 7 is a representative of the class of cultivators with plank-runners and two pairs of paring-blades. The runners are shod with metal, for durability. The blades are reversible, to throw dirt to or from the hill or drill, and the metallic wing-shields in the rear can be raised or lowered to govern the amount of dirt passing underneath them to the corn. To raise the blades in turning, the driver pulls slightly by the standard-handle in front of him, thus shifting his weight so that it lifts the blades. The security of the plants from injury makes this style of cultivator available in very young corn, and the thorough disposal of weeds by it is an advantage when the season is such as to give weeds a start of the corn.

Steering Cultivator.—The peculiar feature of the cultivator seen in Fig. 8 is the steering-lever in front of the driver, attached near the butt of a tongue pivoted in the hounds. Swaying the lever changes the direction of travel independently of the incidental steering tendency of the team; and thus the gangs can be made to follow crooked rows and avoid plowing up hills standing out of line. On hillsides the gangs can be held from drifting downward. The use of the lever increases the ease of turning at the ends of the rows. This construction imparts more lateral movement to the front than the rear shovels, enabling the operator to work close to the plants, with facility of control to prevent injuring them. By

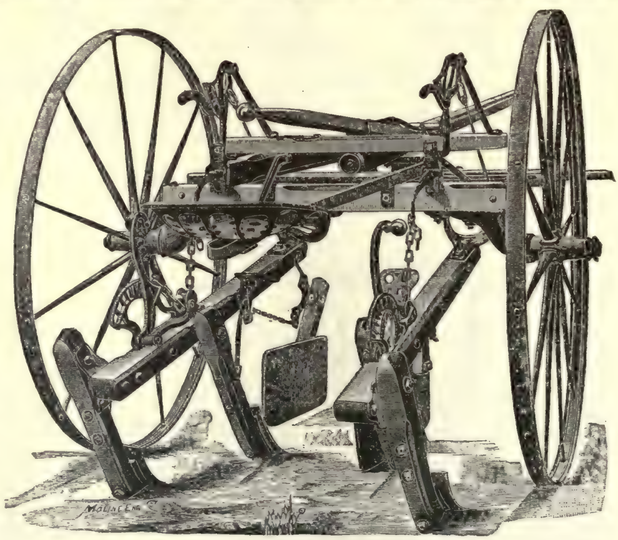


FIG. 8.—Steering cultivator.

treadles the shields are raised or lowered without stopping, governing the quantity of earth thrown to the plant according to its size.

Weir's Tongueless Cultivator (Fig. 9) is rendered light, and allows the team free move-

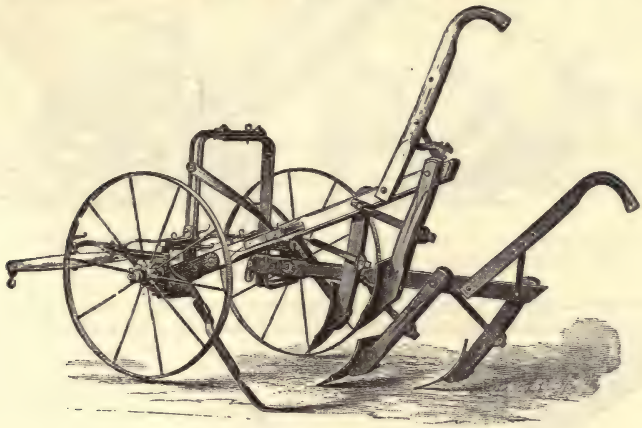


FIG. 9.—Weir's tongueless cultivator.

ment, by the absence of a tongue. It has lateral adjustment of hitch to insure the proper direction for the wheels, in case the team used is unequal in size and step.

The Deere Garden-Hoe (Fig. 10) has two short beams with handles adapted, to propel the

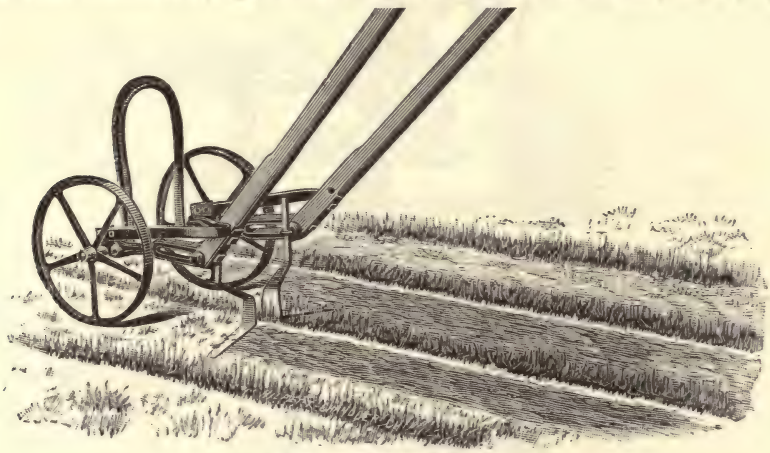


FIG. 10.—Deere's garden hoe.

machine with any of its different attachments, shown in Fig. 11. The handles are connected also with the arch in front by side-springs, permitting instant adjustment to and from

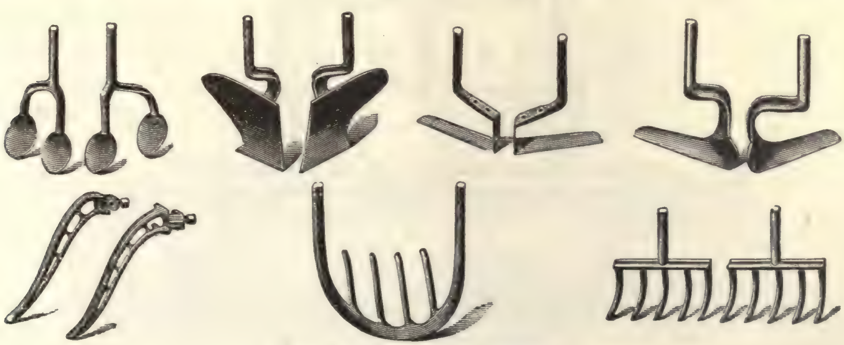


FIG. 11.—Garden hoe-attachments.

the row by the operator. A still simpler hand-implement with wheels, of the same class, is shown in Fig. 12. The two implements last named are for garden-culture.

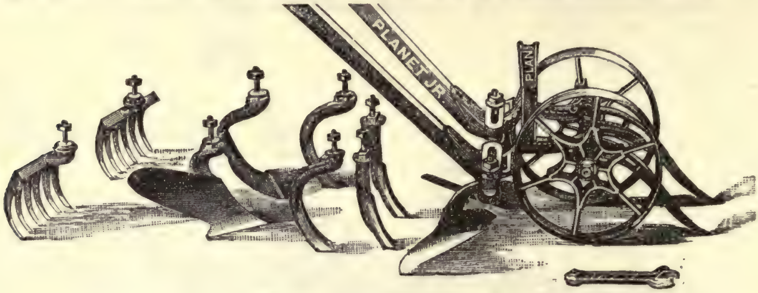


FIG. 12.—Hand garden-hoe.

Beet Cultivators.—Fig. 13 is specially designed for beet-culture. The cultivation of sugar-beets in the United States is beginning to excite lively interest, with a view to beet-sugar pro-

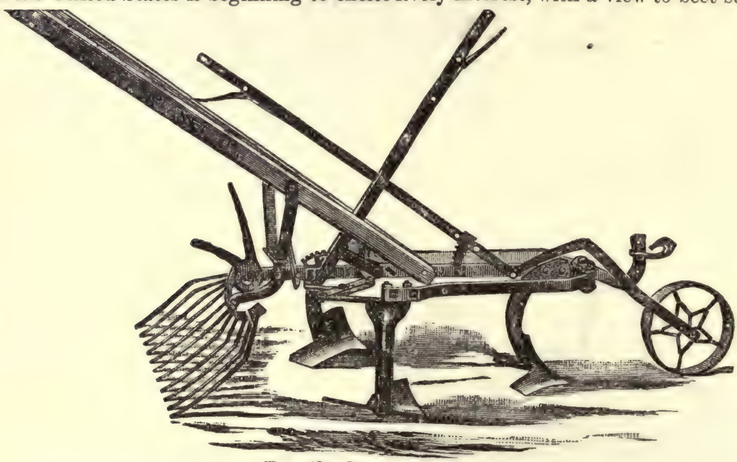


FIG. 13.—Beet cultivator.

duction. It requires thorough tilth and level cultivation—a porous soil, allowing circulation of air and moisture. To insure a mellow seed-bed the plow is run six or eight inches deep,

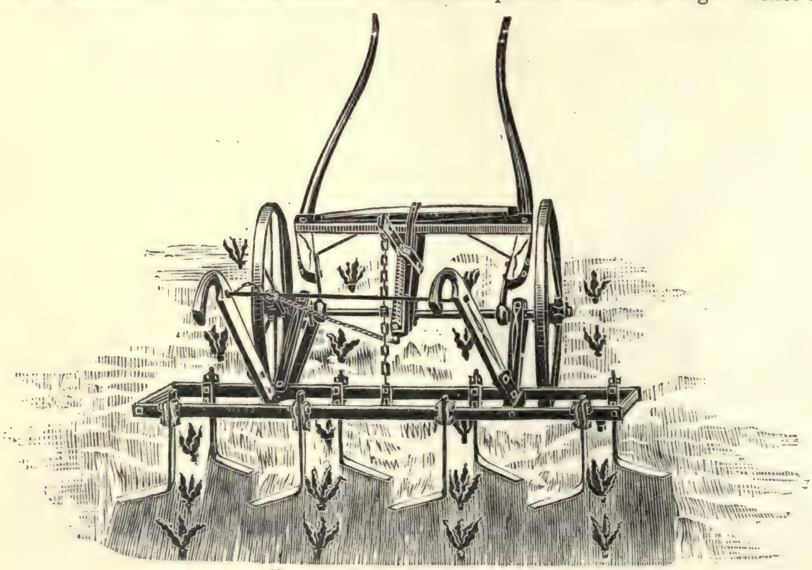


FIG. 14.—Moline beet cultivator.

followed immediately by the subsoil plow to stir the underlying soil to the depth of upward of one foot below the surface in the autumn; and thorough spring harrowing, followed by rolling, and the drills are fourteen to eighteen inches apart, one inch deep. The cultivation should be repeated every two weeks or oftener, until the beet-leaves cover the ground: when the plants may be left until ripe and plowed out from the ground. The yield of sugar depends largely on care and cultivation at the proper time. The seed is often drilled in rows and thinned out when a sufficient growth is reached. The time for thinning is when the plant shows four leaves; this is often done by driving the cultivator crosswise, cutting out surplus plants, and leaving the hills in rows. Fig. 14 is the Moline beet-cultivator, just introduced. The tooth-frame adjusts to the truck by two widely separated connections, with pivots permitting easy hand guidance, to avoid injuring the plants; and the depth of cut is regulated by a center chain inclined forward, and attached at the front end to a standard, self-locking, when the handles are raised, by pawl and ratchet, and unlocked by a lanyard.

Crushers: see Clay-Working Machinery and Ore-Crushing Machines.

Curling Machine: see Hat-Making Machines.

Cutters: see Bolt Cutter, Book-Binding Machines, Coal-Mining Machines, Ensilage Machinery, Gear-Cutting Machines, Grinding Machines, Key-Seat Cutters, Lathe Tools, Metal Milling Machines, Molding Machines, Wood and Stalk Cutters.

CYCLES. The term "cycle" may be considered as generically applicable to that general class of vehicles that has aptly been called the man-motor carriage, of which the unicycle, bicycle, tricycle, and velocipede are types.

If we exclude the Johnson bicycle, patented in England in 1818 (which was a mere rolling support for the rider, placed between the legs, so that his feet touching the ground, and, moved as in walking, would carry him and his support along), the honor of inventing the bicycle is now accorded to a Scotchman, one Gavin Dalzell, some time in 1846. This wheel, said to be yet in existence, finds almost its exact counterpart in the "rover" or "safety" bicycle of the present day. Its rear wheel, 40 in. in diameter, was the driver, the cranks of which were connected by rods with oscillating foot-levers pivoted to the machine-frame; the front wheel, about 30 in. in diameter, was mounted in a fork having a slight rake, which in turn was journaled in the forward part of the frame, the upper end of the fork having a pair of handles turned rearward within convenient reach of the rider, who sat about midway between the two wheels. Pierre Lallement was the first patentee of the bicycle, in 1866. He was a Frenchman, then residing in the United States. This machine, afterward popularly termed the "bone-shaker," had the cranks placed on the axle of the front wheel, which thus became the driving as well as the steering wheel; the rider applied his feet directly to the cranks. Cycles may be classified into three divisions: ordinary bicycles, safety bicycles (including those of the dwarf variety), the Otto bicycle, and tricycles, including sociables, tandems, and carriers.

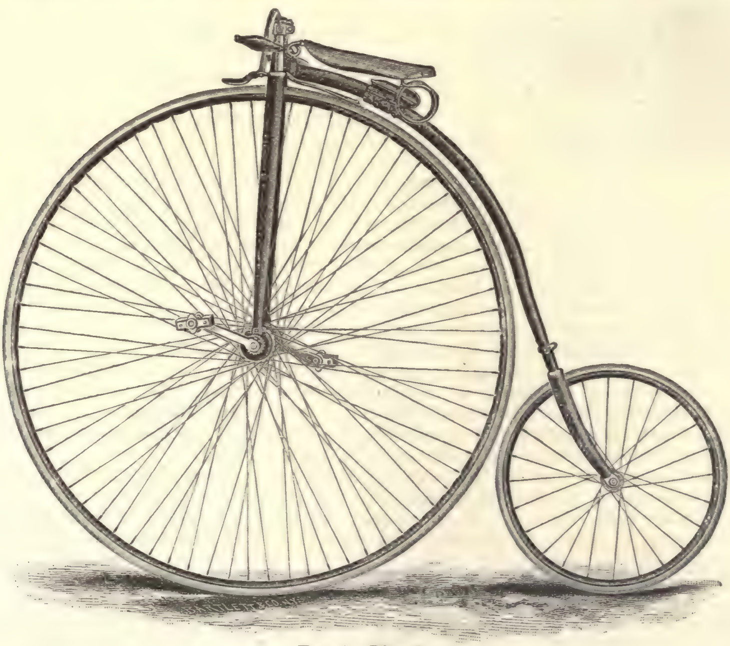


Fig. 1.—Bicycle.

Bicycles.—The ordinary type of bicycle, illustrated by Fig. 1, hardly needs description. As it is supported on only two points—namely, its two wheels—it is necessarily unstable, and will fall to one side or the other. One of the points is movable on being turned sidewise,

which, when the bicycle is in motion, constitutes an act of recovery, caused by turning the wheel toward the side to which the machine is falling; the balance is recovered, and the equilibrium is thus maintained by continually turning the wheel toward one side or the other. The rider is seated slightly behind the center of the driving-wheel, so that he is able by means of his feet alone to control the steering, and to maintain his balance, the cranks in this case forming levers with which to turn the wheel to either side as required. This action requires, during the pedaling movement, a counteracting stress on the handle-bar, otherwise the machine would fail to run steadily.

The weight of the ordinary roadster bicycle varies according to the diameter of the driving-wheel, extending, in the case of a racer, from 18 lbs. upward. One authority distributed the weight of a 54-in. bicycle among its several parts in the following approximate proportions: driving-wheel with cranks, 40 per cent; small rear wheel, 7½ per cent; front fork with head, handle-bar and brake-fittings, 25 per cent; backbone and spring, 17½ per cent; saddle and pedals, 10 per cent.

One of the chief improvements over the old Lallement machine has been the introduction of rubber cushions on various parts of the machine for absorbing and lessening the vibration, which is one of the great discomforts of cycle-riding. Thus, each of the wheels is provided with rubber tires; rubber cushions have been provided around the bearings of each of the wheels and to the handle-bar bearings; the suspension of the seat-spring upon rubber buffers; and also applying springs to the fork of the driving-wheel, interposed between the wheel-bearings and the fork proper.

It was, however, through the introduction of "suspension" wheels that the first real advance was made in cycles, as by such principle of construction the wheels are very light, rigid, and strong. They are constructed either with solid or hollow rims, the latter being lightest and strongest, and the spokes are direct radial spokes or tangential spokes. The spokes are threaded through holes in the rim and screwed direct into the flanges of the hub, being butt-ended or enlarged at the threaded portion, so that the sectional area of the spoke is not diminished by the cutting of the thread. Hollow rims are made in three ways: by being rolled out of a length of solid-drawn steel tube; by being built up of two or more strips of steel plate first rolled to the required section and then brazed together; and by being rolled or drawn out of a single strip of steel plate, the edges of which form a lap-joint, which are brazed together. The rubber tires are constructed of a round or half round section, with either a plain or a corrugated surface, and either solid or hollow. A popular form of hollow or cushion tire is shown in Fig. 2.

In some they are made of hard and soft rubber, the hard forming the wearing surface and the soft the abutting surface or cushion. The tire is generally fixed to the rim by being cemented in it. A wire, however, has been passed along the center of the tire, the two ends secured together by a right and left handed nut. Various sections of rims have also been used for holding the tire without extraneous aid. It is questionable, though, whether there is not a want of cohesion between the rim and the tire in this method.

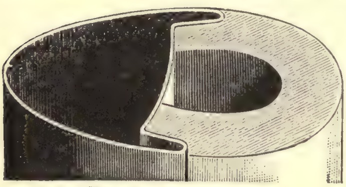


Fig. 2.—Cushion tire.

The tangentially arranged spokes were adopted because of a certain amount of windage which takes place before the power is transmitted to the rim through the spokes. In the tangentially arranged spokes they are generally arranged in pairs, each pair being threaded through a hole in the flange of the hub, with their outer or free ends fixed to the rim by lock-nuts or nipples. One of the recent forms of tangential spokes is to use single instead of pairs of spokes threaded through transverse holes in the hub, and bent to run off at right angles to the hole, and thus form a kind of hook. The spoke-ends are also headed, to prevent them from pulling through the holes, and secured to the rim by nipples or lock-nuts.

Another form of spoke is the corrugated or crimped spoke, corrugated throughout its entire length, which gives a certain amount of elasticity to the wheel.

The bearings of the wheels are now invariably made with anti-friction balls interposed between the moving parts. Many have thought that this method of easing the running parts was an invention which came in with the improved bicycle, but such anti-friction balls and rollers had been proposed and described for use with axles as far back as the year 1787, and other patents for similar contrivances were granted in 1791 and in 1794.

One of the successful kind of ball-bearings is that known as the "Æolus" bearing, in which the adjustment is concentric, so that the bearing remains perfectly true after adjustment. In another form, shown in Fig. 3, there are two facing cones, only one of which is moved in adjusting to take up the side-play or check. One enterprising gentleman by careful experiment found that 12 balls in a bearing lost together $\frac{1}{20{\cdot}8}$ gr. in weight in running 1,000 miles, or only $\frac{1}{250}$ gr. per ball, equaling an actual surface wear of only $\frac{1}{158000}$ in.

The frame of a bicycle is generally constructed of weldless steel tube, and consists of two essential parts, the front fork and the backbone.

In order to give extra strength to the fork, to enable it to resist the torsional strain pro-

duced by the rider's pulling upon the steering-handles, it is generally drawn and tapered into an oval section, while the backbone is of circular section, although somewhat tapered toward

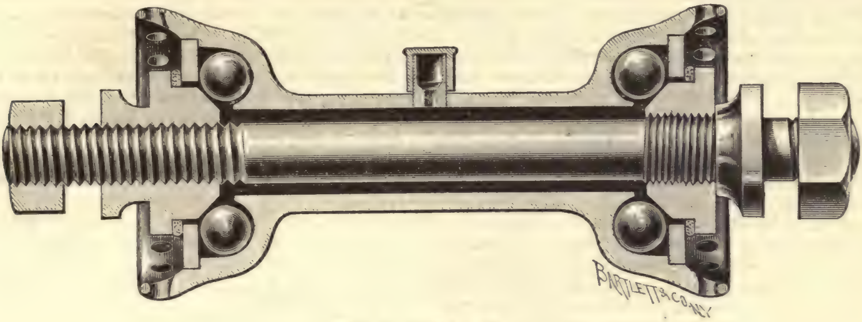


FIG. 3.—Ball-bearing.

the point where it is usually brazed to the backbone. This latter is bent and blocked into shape from a blank of sheet-steel, the sides being usually of a half-round section. Frequently, however, the back fork is simply a prolongation of the backbone proper. The front fork is made rigid between the axle and front end of the backbone.

Bearing in mind that the front wheel is the steering-wheel, and that this is carried in the vertical front fork, the method of mounting and controlling the wheel must be considered.

At the top of the fork is a socket or head pivotally connected by a short spindle with the front end of the backbone, coned bearings being provided at each end of the spindle. A transverse bar having handles at both ends, and fixed upon the head just mentioned, serves to control the steering-wheel, and affords also a steadiment for the rider. A brake-handle is pivoted to the handle-bar in such way as to be easily grasped by the rider without releasing his hold on the bar. The brake now almost invariably used on ordinary bicycles is termed a "spoon-brake," and consists of a spoon-lever so pivoted in the head as to be easily brought to bear upon the circumference of the driving-wheel. The leverage is so arranged that great power is obtained, and care must be exercised in applying it so as to prevent sudden stoppage, which results in the rider being thrown off.

The saddle is of leather, and in some of the most popular types of machine is made detachable from its frame or support, which is mounted upon the backbone close behind the front fork, so that the rider's feet may conveniently reach the pedals. Different forms of steel springs are used in making up the saddle-frame, and these have an adjustable tension for riders of different weights. Devices for adjusting the saddle fore and aft and for altering the pitch of the seat are also now invariably employed.

The pedals are made in several varieties, the chief forms being known as "rubber" and "rat-trap"; they are mounted upon pedal-pins bolted to the cranks, which are in turn fixed to the axle of the driving-wheel. The rubber surfaces tend to absorb a great deal of the vibration, and also afford a good grip for the rider's shoe; the roughened steel plates in the "rat-trap" type excel in the latter particular, but lack the power of taking the vibration. A combined "rubber" and "rat-trap" pedal, constructed with rubber on one side and serrated plates on the other, is largely used, and found to give the advantage of both varieties. Two square blocks of rubber, serrated upon their surfaces, and pivoted within the pedal-frame, are also favorably known as affording adjustment to the curve of the foot. Foot-gripping devices are also used with pedals in various forms.

A peculiar and popular type of bicycle is found in that called "The Star." It has a large driving-wheel driven by pedals, which in their alternate up-and-down motion actuate ratchets formed upon the driving-axle. The rider's seat is over this wheel, slightly in front of its center, and the backbone extends downward in front, where it is forked over a small steering-wheel. The frame, including the backbone, is practically triangular in shape, with a branch for the seat-support, and this frame is so pivoted that the front wheel—besides moving sidewise in steering—may be raised from the ground at the will of the rider by correspondingly moving the handle-bar. This machine is often used for the unique purpose of playing the game of polo. The contestants, mounted upon "Star" bicycles, follow the ball to and fro between the goals, and use the small front wheel as a bat, in driving the ball in the desired direction as well as for checking it in its course.

Another ratchet-pedal action is found in the "Eagle" machine. Here the wheels are situated as in the ordinary bicycle, but instead of a rotary motion being imparted to the pedals, a simple up-and-down movement in the arc of a circle is the result of the rider's efforts, and this operates through ratchets to revolve the driving-wheel.

The accessories and fittings of bicycles, such as tool-bags, lamps, bells, lubricators, distance-indicators, etc., are too numerous in form for description; their manufacture affords employment to many artisans of different trades, and involve the investment of large amounts of capital.

Before proceeding to consider the next important form of bicycle—the "Safety"—it is necessary to look briefly at the type called "Dwarf" bicycle, this being the immediate fore-

runner of that successful and desirable cycle which permits the use of a small driving and steering wheel.

In one class of the "Dwarf" machine the power, instead of being applied direct to the driving-wheel, is transmitted to it through a pair of endless chains and sprocket-wheels from a divided pedal-axle carrying a crank, placed below and slightly in rear of the driving-wheel axle, so that the rider's feet are much nearer the ground, and his seat correspondingly lowered. This construction permits of gearing-up, so that the wheel may be equal in speed to any desired size of driving-wheel, and also allows the use of long cranks, independent of the length of the rider's legs. This accounts for its ease of propulsion, and consequent speed, for it is admitted that the internal friction in this machine is greater than in the ordinary ungeared machine, and its weight certainly no less; therefore the theory must be that the low speed of pedaling does not produce so much exhaustion as is experienced from a more rapid movement of the legs.

A machine of this class may be adjusted, within certain limits, to suit riders of any height, by raising or lowering the pedal-axle brackets and altering the length of the chains. By having the lower end of the fork pivoted to the upper branch at the center of the wheel, and by turning the brackets to an angle and then tightening-up, the height of the pedal-axle from the ground may be varied without altering the length of the chains.

"Dwarf" bicycles are also propelled by a lever-action, and this type is commonly known as "Kangaroo," and frequently as "Grasshoppers." The fork of the front wheel is extended below the driving-axle, and on the ends are pivoted two pedal-levers, worked at their free ends with the feet; these pedal-levers work the cranks or the wheel-axle through connecting-rods so arranged as to increase the leverage. The action of the feet is a reciprocating one, the path of the pedals being simply the arc of a circle, of which the radius equals the length of the lever, and the reciprocations of the rider's feet are just equal in number to the revolutions of the driving-wheel.

Another type of lever-action "Dwarf" machine has the pedal-levers suspended from links pivoted high up on the branches of the fork, and the pedal-levers are themselves connected direct to the cranks, and curved backward to bring their free extremities properly under the rider's feet. The path or travel of the pedals is elliptical, or a mean between the arc of the reciprocating and the complete circle described in the purely rotary machines. The front fork is made to rake backward, so that the curve of gravity is kept well behind the axle of the driving-wheel; and, owing to the consequent safe position of the rider, a larger driving-wheel can be used without seriously curtailing the safety of the machine. On account of the lowness of the seat, the rider can not use the handle-bar as a rest for his legs in "coasting," as is done with the ordinary wheel. The "Dwarf" machine has usually a pair of foot-rests extending forward of the axle on extensions of the fork.

The bicycle having reached this point in its development, it only remained for the process of evolution to produce the present standard form of "Safety" machine, shown in Fig. 4, which is largely in use by persons of both sexes, from the child to its grandparent.

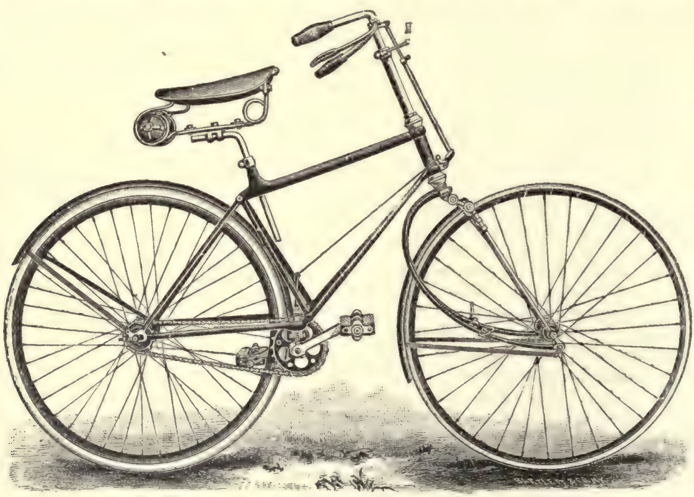


Fig. 4.—"Safety" bicycle.

Having all the favored appliances of the most approved ordinary roadster, such as cushion and pneumatic tires, ball-bearings, adjustable seats, etc., this machine possesses the elements of safety and speed to an almost perfect degree.

The front wheel is used for steering and the rear wheel for driving, both being of the same diameter, viz., usually 30 in., geared to 54 in.

The pedal-shaft is carried in the frame just in front of the driving-wheel, its center being slightly lower than that of the wheel, and an endless chain imparting motion from a sprocket-

wheel upon one end of this pedal-shaft to a wheel of the proper relative size on the driving-wheel axle. The bracing-bars of the frame, all of forged steel, are arranged in different ways —a preferred form of frame in men's bicycles being that of an elongated diamond, the sharper apexes being at the rear axle and front fork, and the other angles occurring at the pedal-shaft and the point where the saddle is supported, a cross-bar lying between the two latter. The front fork is rigid, and made with a curve and "rake" rearward from the front-wheel axle, so that the handle-bar may be within convenient reach of the rider's hands, and the saddle lies just over the front half of the rear or driving wheel.

The Ladies' Bicycle (see Fig. 5) is similar to the above in all respects, save that the backbone of the frame extends downward from the head of the fork close to the rear part of the front wheel, and then curves underneath to a junction with the pedal-axle. Skirt-guards are provided over the moving parts adjacent to the rider's seat. For ladies' use, the present standard diameter of wheel is 28 in., geared to 50½ in. The brake is of the plunger type in

FIG. 5.—Ladies' "safety" bicycle.

both machines, and is applied to the driving-wheel, and the handle-bar is a single tube of seamless steel tapered at each end and curved backward, to bring the grasping pieces, which are of rubber, within easy reach of the rider's hands.

The spokes preferred in these standard "safety" machines are of the double-tangent type.

As a result of continued and practical investigation by experts in this country and England, an efficient anti-vibration device, in addition to the cushioned tires and hubs, has been deemed an essential part of a high-grade modern bicycle; a yielding spring-fork, of which that named the "Victor" is a leading type, has been largely adopted.

It is of especial value for rough-road riding, where obstacles are frequently met with, and great strain consequently brought to bear upon the machine.

The front fork consists of two steel bars "raking" backward from the axle of the front wheel, and pivoted to short links, which are also pivoted to the head, which practically forms part of the frame. Two strong steel springs, bowed toward the rear, extend from the steering-wheel axle, one on either side of the wheel, to a rigid connection with the lower part of the head. The springs carry foot-rests. By referring to Fig. 4, the action of this spring-fork will be understood without further explanation.

The spring-fork is equally applicable to ladies' bicycles.

The Otto Bicycle is the invention of a brother of the inventor of the gas-engine bearing the same name, and probably is the only one of its class, it being believed that no other bicycle exists in which the whole weight of the machine itself, as well as the full weight of the rider, rests upon the driving-wheels.

It is in some respects more nearly *allied* to a tricycle than to the bicycle proper, but, as it has only two wheels, and consequently requires the balance to be still maintained by the rider, it is rightly called a bicycle. The wheels are of equal size, and are here mounted loose on the same axle, parallel to each other, and both of them are drivers. The rider sits between them, and works a continuous pedal crank-axle, the position of which, when he is seated, is below and slightly in front of the axle carrying the driving-wheels. The crank-axle is connected with the driving-wheels by endless steel bands passing around plain pulleys on the ends of the crank-axle and on each wheel. The bands are kept taut by tightening springs, and the machine is steered by slacking one or other of them, which causes the corresponding driving-wheel to lose motion, and therefore the other wheel overruns it. If a sharp turn has

to be made suddenly, a brake is applied to one wheel at the same time that its driving-band is slackened, which causes the machine to turn round in a circle upon that wheel as the center. This machine, having no small wheel fore or aft the rider, while steady sidewise, has to balance himself in the direction of his motion, which he is enabled to do through the medium of the pedal crank-axle: by pressing on the forward pedal, if he is falling forward, he throws his weight backward; and by pressing on the rear pedal, if he is falling backward, he throws his weight forward. To prevent him from actually capsizing backward, a safety-tail projects behind upon the ground whenever the seat is tipped too far back. Among the many beautiful features presented by this machine, the best seem to be: Firstly, its balance, whereby the rider is always in the best position to utilize his strength and weight, notwithstanding the varying gradients; secondly, the nicety with which it can be steered; thirdly, its tendency to run in a straight line without any effort on the part of the rider; fourthly, its freedom from vibration; fifthly, the circumstance that it makes only two tracks; and, sixthly, the perfect distribution of the wheel-load.

The power required to propel a bicycle on an average road has been approximately estimated at from $\frac{1}{7}$ to $\frac{1}{4}$ of a horse-power, according as the speed varied between 6 and 14 miles per hour, with the odds in favor of a rotary-action against a lever-action machine.

Tandem Bicycles.—One of the earlier machines of this class is constructed of two ordinary bicycle driving-wheels complete in their forks, which latter are connected by a backbone, having in its length a swivel or axial joint. Each rider drives his own wheel, sitting just behind its center, and each steers independently of the other for balancing himself. The axial joint in the backbone, and the joints formed by the heads of the forks and the bearings of the wheels, together make a perfect universal joint between the two wheels. Within certain limits the rear rider has of course to follow in the track of the front wheel; otherwise the heads of the two forks become locked, and a dismount is rendered necessary. Although this machine is very fast, lighter than two ordinary bicycles, and almost entirely free from vibration, there is an element of danger about it that militates against its general use, inasmuch as it demands to a certain extent a unity of thought and action on the part of the two riders.

The Tricycle, as its name implies, is a three-wheeled machine, each one of which wheels must be free to move in its own direction, independent of the united action of the other two. For running in a straight line, all three wheels must be parallel; while for running round a curve, one or more of the wheels must be turned uutil the center lines of the axles intersect in plan, their point of intersection being the center of the curve round which the machine will then run; therefore, the more acute the angle of intersection, the greater will be the radius of the curve; and, inversely, the more obtuse the angle, the sharper will be the curve. Besides being independent in the direction of running, each wheel must also be capable of revolving at a greater or less speed than the others. It is also essential that the greater part of the rider's weight shall be on the driving wheel or wheels, and that only enough shall be on the steering wheels or wheel for insuring their proper action. Owing to the variety of ways in which these principles can be carried out practically, it is easy to account for the variety of tricycles constructed.

The simplest form of tricycle is obviously that with only one driving-wheel, either or both of the others being used for steering. An early type of single driver, now practically obsolete, had two large wheels mounted opposite and parallel to each other, one of which was driven, and the other was allowed to run free; the third, or steering wheel was placed centrally in the rear.

Another form of single driver has the large driving-wheel on one side, and two small steering-wheels on the opposite side, placed respectively fore and aft of the driver, and arranged to turn together, bnt in contrary directions. The double steering, fore and aft, of the driving-wheel overcomes the tendency of the machine to run in a curve, in consequence of the single driving-wheel on one side. This was one of the first tricycles introduced, and has stood the test of competition, being at the present time one of the most popular. Its chief features are that it is simple in construction, makes only two tracks when running, and is narrow in width. Its narrowness, although rendering it somewhat unstable in running round a curve at a high speed, allows of its passing through a doorway of ordinary width.

The third and last kind of single driver has the driving-wheel placed centrally in the rear of two steering-wheels, which are mounted parallel and opposite to each other. The defect of this arrangement is that the weight of the rider is too equally distributed over the three wheels, instead of coming more upon the driver than upon the other two.

There are several types of double-driving tricycles, where the two driving-wheels are placed parallel and opposite to each other, with the steering-wheel in front or behind, and generally central, though in some cases it is placed in line with one of the driving-wheels, so that the machine then only makes two tracks.

The two principal methods of double-driving are: first, by clutch-action; and, secondly, by differential or balance-gear.

In the clutch-action plan the two driving-wheels, or the chain-wheels driving them, are locked to their axle while the tricycle is being driven straight forward, but in running round a curve the outer wheel overruns the clutch, and the inner wheel alone drives. Of the various clutches so far devised, probably the best results have been attained by that known as the Bourdon clutch. It consists of a disk fixed upon the crank-axle, and having its circumference cut away so as to form a series of inclined planes. A box forming the boss of the chain-wheel encircles this disk, and in the recesses of the inclined planes which join between the disk and the

box, and so lock them together as long as the axle is driving the wheel. Whenever the wheel has freed itself by overrunning the axle there will always be at least one of the rollers ready (in every position) to instantaneously lock the two together again as soon as the speed of the wheel falls back to that of the axle. The pedals can remain stationary whenever the gradient of the road will allow the machine to run of itself, an advantage which economizes the expenditure of power, as the feet of the rider can remain motionless for the time being. The brake, however, must be entirely relied on for checking the speed, as it can not be stopped by back-pedaling. A clutch-driven machine can not be driven backward without some extra gearing. Many attempts have been made to construct a clutch that will drive automatically in both directions, but the writer is not aware that any have proved successful, the reason of their failure being that they were not instantaneous in action.

The mode of double-driving by differential or balance gear—so called because the power is divided or "balanced" between the two driving-wheels—employs an epicyclic train in which the two primary wheels are each connected directly or indirectly with one of the driving-wheels of the tricycle, and also connected with each other through an intermediate loose train. One of the simplest forms of differential gear somewhat resembles an ordinary reversing train; one of the two facing wheels is fixed to the hub of one of the driving-wheels, which runs loose on the axle, and the other facing-wheel is fixed on the driving-axle. on the hub of which is fixed the other driving-wheel. Between the two facing-wheels a chain-wheel is mounted loosely on the axle, and this carries loose on a radial axis a bevel pinion-gearing permanently with both facing-wheels.

When the tricycle is running in a straight line, both driving-wheels are driven equally by the chain-wheels, the two facing-wheels meanwhile being drawn round by the intermediate pinion, which at that time is idle.

But when the tricyle travels in a curve, the inner driving-wheel revolves at a slower rate than the outer wheel, and consequently the outer driving-wheel is driven through the bevel-gear at a consequently higher speed, in whichever direction the machine is running, whether forward or backward.

As already described in regard to bicycles, there are two methods of driving a tricycle: Firstly, by rotary action, in which the power is applied either directly to a cranked axle carrying the driving-wheels, or to a cranked pedal-axle connected with the driving-wheel axle through an endless chain or other means; and, secondly, by lever-action, where the power is applied by reciprocating pedal-levers, from which the motion is communicated to the driving-wheel axle through cranks and coupling-rods, or otherwise. The lever-action lends itself most aptly to obtain varying power; but in speed the rotary action is superior. The reason would seem to be that in the lever-action the direction of force is changed so suddenly that in rapid pedaling a certain amount of back pressure is unavoidable.

Of direct-action or rotary tricycles, the simplest form has two driving-wheels mounted on the end of a cranked axle, and connected to it by clutches, the rider driving the axle direct. This arrangement simplifies the construction and reduces the working parts; but the high position of the center of gravity offers an objection to the stability of the machine.

The swinging pedals are sometimes hung from the cranked axle, thus lowering the center of gravity, and rendering the machine more stable.

A successful lever-action machine is called the "Omnicycle," which is fitted with a variable-power gear.

The pedal levers are connected by bands to two expanding segments connected by clutches to the driving-axle, and to each other by a reversing apparatus, so that the forward movement of the one produces the backward movement of the other, thus the descending pedal raises the other ready for the next stroke.

The frames of tricycles are largely constructed of weldless steel tube, and their contour and general arrangement vary with the different types of machine. Malleable-iron castings have been used in many of the solid parts.

The steering-gear of such tricycles as have a single steering-wheel is usually the same as that of a bicycle, employing a transverse handle-bar; but another method, using a rack and pinion, is frequently adopted. The pinion is fixed to a vertical handle, mounted in bearings, so that it can revolve; and the rack forms part of a light rod, the free end of which is connected with an arm fixed on the fork of the steering-wheel.

In each different make of tricycle there is a certain position for the rider's seat, in respect both to the axle of the driving-wheel and also to the pedal crank-axle, so as to permit the rider to exert his power to the best advantage. The best position for the seat on a front-steering tricycle is generally 1½ in. in front of the driving-axle, and 7 in. behind the pedal-axle, this axle, therefore, being 8½ in. in front of the driving-axle.

The above-described tricycles are types of those manufactured and used in England, where such machines find much more favor than in the United States.

The only form of tricycle which has been extensively made and sold in this country is shown in Fig. 6. It is called the "Surprise Columbia Tricycle," and has a 32-in. rear driving-wheel, operated from the pedals by sprocket-wheels and a connecting chain.

There are two 26-in. front steering-wheels, journaled on the ends of a cross-bar or axle, forming part of the frame, adapted to be adjusted so as to vary the width of the running-track as well as to be folded, to still further reduce the width, in order to enable the machine to pass through ordinary doorways. The width is variable, between 34 in. and 29 in. all over.

The wheels, crank-shaft, and pedals are fitted with adjustable ball-bearings, and the wheels

have rubber tires cemented into the felloes, and direct spokes headed at the felloe and screwed into the forged steel hub-flanges.

For steering, a lever-arm at the bottom of each steering-head is connected by a high rod to a lever pivoted below the main-frame bracket, and taking its motion through a connecting-rod attached to the lower end of the handle-bar upright. The brake is similar to that of a bicycle.

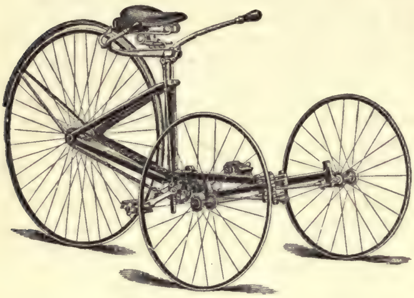


FIG. 6.—Tricycle.

Hand-Power Tricycles have been introduced from time to time, notably the Oarsman and Velociman. In both of these driving-power is exerted by the arms instead of the legs. Their use, however, is very limited, being only of service in particular instances.

Sociable Tricycles.—This type is merely an enlargement of the single form of tricycle, so as to permit two riders to sit side by side. Some "Sociables" are capable of being converted into single machines.

Tandem Tricycles are constructed so that the riders sit one behind the other. The tandem principle is applied to most of the principal forms of tricycle, notably to those differentially geared; the front-steering type, by using an auxiliary trailing-frame with transverse and vertical joints between it and the front frame: and to the rotary machine by the addition of a light frame fixed in the rear of the front seat, to carry the hind seat and pedal crank-axle for the rear rider. Tandems of several classes are made convertible into single machines.

Carrier Tricycles.—The last kind of tricycles is one capable of being put to practical use for carrying a burden. There is one form known in England as the "Coventry Chair," where a passenger is carried in a comfortable chair constructed in the front part of the machine, and the driver's seat and driving mechanism, similar to that of the ordinary tricycle, are located between the driving-wheels in rear.

(See *Cycling Art, Energy and Locomotion*, by R. P. Scott; and *Construction of Modern Cycles*, by R. E. Phillips.)

Damper Regulator: see Regulators.

Derrick: see Crane.

Diamond Drill: see Drills, Rock and Quarrying Machinery.

Dies: see Brick-Making Machinery, Milling Machines and Pipe Cutting and Threading Machines.

DIGESTERS, LIME SULPHITE FIBER. Sulphite fiber, or pure wood cellulose, supersedes rag stock in paper-making. The wood in chips or disks is boiled in great digesters with a solution of bisulphite of lime, and the main engineering problem lies in the construction of a suitable, economical, and lasting digester.

The following notes on digesters are condensed from a valuable paper on Lime Sulphite Fiber Manufacture in the United States, by Major O. E. Michaelis, U. S. A. (see *Scientific American Supplement*, No. 732, 1890): Exteriorly all the digesters are of metal, all of open-hearth steel or iron plate, except the Schenk, which is of so-called deoxidized bronze. All are approximately cylindrical, except the Partington, which is spherical. The cylinders are upright in the Ritter-Kellner and Schenk processes; in the Mitscherlich and Graham they are horizontal. The digesters are fixed, with the exception of the Partington and Graham, which revolve, the Graham about its longer axis. Considered merely as a vessel strong enough to stand a given pressure, the only available substance of which the digester can be made, looking from an economical standpoint, is iron or steel. The majority of the digesters are made of rolled iron plates; the Detroit, of open-hearth steel. There is no reason why our gun-iron, with a tensile strength approximating 40,000 lbs., should not be available for digesters. They could be turned out in sections ready for assembling; the advantages of such a substitution for the complicated rivet-work shell are evident. At remote inland points the large digesters must be assembled *in situ*, and boiler-makers must now be transported for the purpose. A properly handled wrench would suffice to set up the sectional cast-iron construction. A 14×40 ft. cast-iron digester has been designed, with a factor of safety of 6, which will cost less than the riveted apparatus, to say nothing of the facility with which it can be transported and the ease with which it can be assembled by unskilled labor. We come now to the inside of the digester. Owing to the well-known affinity of the bisulphite solution for iron, all digesters made of this metal must be lined with a resistant, fluid-tight material, as a protection against the solvent action of the "acid" mixture. The Schenk digester, a unimetal construction of deoxidized bronze, is assumed to be sufficiently resistent to the solution without protecting lining. The Graham, Partington, and Ritter-Kellner digesters are all lead-lined, the Mitscherlich fire-brick lined. The bricks used are of special form, made of a German refractory clay the same as used in the manufacture of the Nassau Seltzer jugs.

Digester Linings.—The vital point in these sulphite processes lies in the ability of the digester to resist the erosive action of the acid solution and its gaseous products. Lead has for centuries been used as a lining material in the manufacture of sulphuric acid, so that its application to the present sulphite fiber processes lay near at hand. It is used in the Graham, Partington, and Ritter-Kellner digesters. In speaking of the sulphite process the *Encyclopædia Britannica* uses the following language: "The pulp or fiber produced by all these

processes is of excellent quality, and can be prepared at a cost greatly lower than the soda process. The strength of the fiber is maintained unimpaired even after bleaching, and white paper made solely from such fiber is in every respect superior to that manufactured solely from pulp prepared by boiling with caustic soda. Dr. Mitscherlich's process has been extensively adopted in Germany, and there seems little doubt that these processes will in time supplant the use of soda in the case of wood. The great objection to them all is that, as they all depend on the use of bisulphite, which, being an acid salt, can not be worked in an iron boiler, the boiler must be lined with lead, and great difficulty has been encountered in keeping the lead lining of the boiler in repair."

The primary, indispensable condition in protecting iron sulphite boilers with lead is that the lining must be continuous—that is, liquid-tight. Now, lead has a linear coefficient of expansion much more than double that of iron; in these processes it is subject to a change of temperature of at least 240° F. (300°–60°), and the unavoidable resulting flow of the metal can not be compensated for by permitting sections to expand and to contract freely upon each other, for that would require open joints, a violation of our primary condition. The lead lining must in some way be attached to the iron shell, for otherwise it would soon collapse, or go to pieces in some other way. Only three practical ways offer themselves for the attachment of the lead lining to the iron. It may be bolted on at proper points; it may be, to borrow a plumber's phrase, "tacked on" at appropriate places, or it may be completely soldered on. The first two methods permit, as is evident, under variations of temperature, changes in the superficial area of the lining; the latter method forcibly resists this, and limits the flow of the lead during the life of the solder union to molecular expansion only.

The Partington Boiler is spherical; the lead is applied in spherical lunes, clamped to the iron, and burned to each other. The theory is, that it is an easy matter to replace an injured section, and thus to keep the lining intact at comparatively little cost.

The Ritter-Kellner Digester, about 10 × 28 ft., is built up of cylindrical sections, 4 ft. wide, a few inches apart, and fastened by heavy exterior bands. The object of this construction is to provide the means for attaching the lead lining peculiar to this process. The spaces between these sections form annular dovetail mortises, which are filled with an alloy of lead and antimony, and at the ends of a diameter meet similar vertical tenons, to which they are attached. The lining is burned fast to this semi-cylindrical frame. Here, again, under the irresistible force of expansion, these great sheets of lead, roughly speaking 16 × 4 ft., must theoretically, if the tacking holds, "pucker up," and again be forced back against the shell under contraction and pressure.

The Graham Digester, 7½ × 22 ft., is made of sheets of boiler-plate, to which the lead lining is soldered before bending and assembling. The method of doing this is ingenious and simple. The sheet is cleansed and smoothed by a radially traveling emery-wheel: it is then firmly fixed for half its surface over a gas-jet heater. The rectangular frame that holds it down is packed with fire-proof packing where it rests upon the plate, thus actually forming a water-tight vessel, of which the iron to be leaded is the bottom. The plate is copiously doused with a solution of chloride of zinc, and, when heated to the proper degree, molten lead in sufficient quantity is poured upon it. Although the promoters of this process do not so call it, it is, nevertheless, soldering, which is authoritatively defined to be "the process of uniting two pieces of the same or of different metals by tne interposition of a metal or alloy, which, by fusion, combines with each."

Brick-Lining.—The Mitscherlich Digester is lined with an acid-proof brick of special design, laid in Portland cement. Apparently a startling innovation, reflection proves that this method follows out the direct line of modern progress. The manufacture of that almost indispensable article, sulphuric acid, has in comparatively late years been greatly improved and facilitated by the introduction of the Gay-Lussac and Glover towers, edifices lined, not with lead, but with acid-proof tiles or brick.

Unlined Digesters.—The Schenk Digester is a stationary, upright cylinder, 7 ft. in diameter by 22 ft. height, and is made in sectional castings of deoxidized bronze, with planed flanges, which are bolted together and lead-jointed in assembling. This alloy the designer assumes is sufficiently acid-proof for the purpose, without the protection of other resistant lining. It is acknowledged that the deoxidized bronze is acted upon by the acid solution, and observation confirms this conclusion; but it is claimed that this erosion is so slight that the longevity of the digester is not threatened thereby.

Acid Process.—The manufacture of the bisulphite solution may be classified under three heads: the vacuum process, the modified tower process, the tower process. The vacuum system is used in connection with the Partington, the Schenk, and the Graham processes. It requires large exhaust-pumps, a series of tanks arranged vertically in echelon, a lime-mixer, etc., and undoubtedly yields with certainty the high solution required. It can be used for all the processes. The modified tower system, in use with the Ritter-Kellner process at Cornwall, is a sort of cross between the Mitscherlich tower and vacuum method. The solution is pumped by a battery of pumps into a series of low towers under cover, filled with limestone. The Mitscherlich tower process is in a measure automatic, and is certainly the most economical. The sulphurous-acid gas is drawn up the high towers, filled with limestone, by atmospheric draft, and therein meets water trickling through the filling. Its main disadvantage is the assurance of proper draft. The consumption of sulphur varies from 200 lbs. per ton of fiber in the Mitscherlich up to nearly 600 lbs. in the others. In none of the others is it less than 350 to 400 lbs.

Mechanical Preparation of the Wood.—All the processes, except the Mitscherlich, use

chips. In this latter, disks cut out from the log, 1¼ in. deep, are used. Dr. Mitscherlich claims that these disks afford a stronger fiber, and that more bulk can be put into the digester than if loosely piled chips were used.

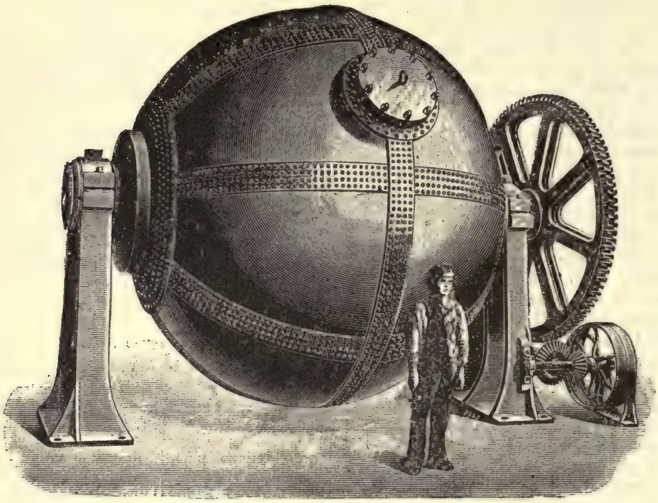


FIG. 1.—Wood-fiber digestor.

A recent form of digester of English manufacture is represented in Fig. 1. It is made of Siemens-Martin mild steel plates, $\frac{11}{16}$ in. thick and 12 ft. in diameter inside. The rivet-holes on the inside are countersunk, to present a level surface to the lead lining, which is patented. The lining is made in large sheets, and is held against the steel shell by means of a series of clamps fastened from the outside. The digester is filled through the man-hole, which is 2 ft. in diameter, from a high level, with timber and sulphite liquor, and steam passes in at a pressure of 70 lbs. through the trunnions, while the digester is slowly revolved by means of the bevel and worm gearing, as shown in the engraving.

Disintegrator: see Clay-Working Machinery.

DITCHING-MACHINES are used for excavating ditches and trenches for drainage, etc. *The Plumb Ditcher* (Fig. 1) cuts the whole ditch in one passage on the required grade. It

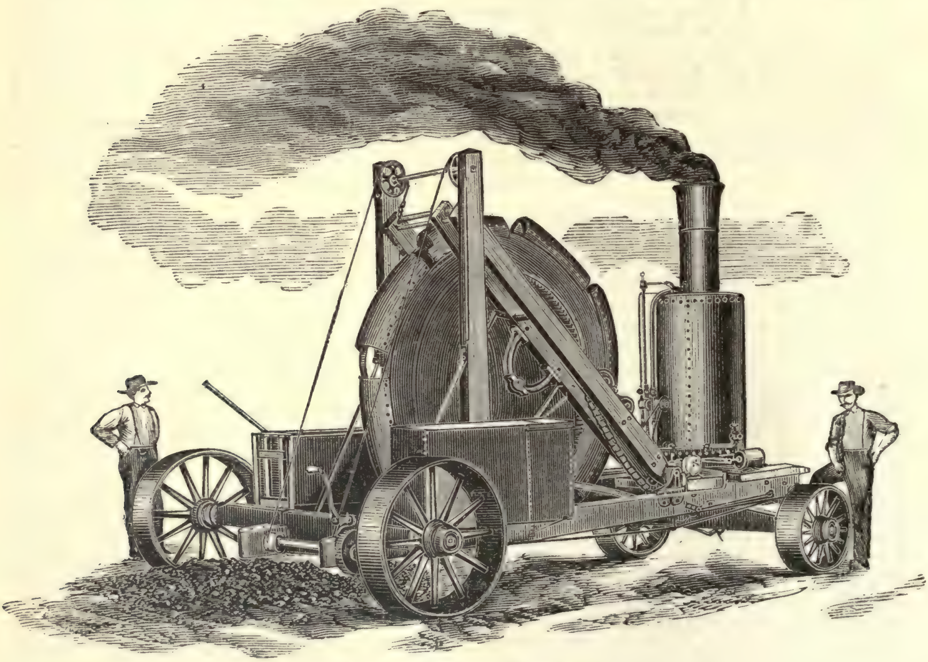


FIG. 1.—The Plumb Ditcher.

consists of an engine and boiler driving a large cutting-wheel, all set in one frame carried on four broad-faced wheels. The machine is drawn forward when working by means of a wire cable passing through a block anchored any distance ahead and winding on a drum on the front end of the machine. The ditch-cutting wheel is formed with rim-scoops, which cut and elevate the dirt-cutting from the bottom of the ditch upward. The cutting-wheel hangs in a

swinging frame raised or lowered at will to maintain the grade line required for the bottom of the ditch, and can cut to a depth of 4 ft. It forms a rounded bottom to the ditch, suitable for the reception of either of the ordinary sizes of farm drain-tile. The dirt is all discharged at one side of the ditch, convenient for refilling. As the wheels are 10 in. broad, the machine works on soft ground as well as hard, even where horses could not be employed.

Potter's Ditcher (Fig. 2) is drawn by animals, and, being a comparatively light machine, performs its work by passing repeatedly over the same job until the ditch is brought to the

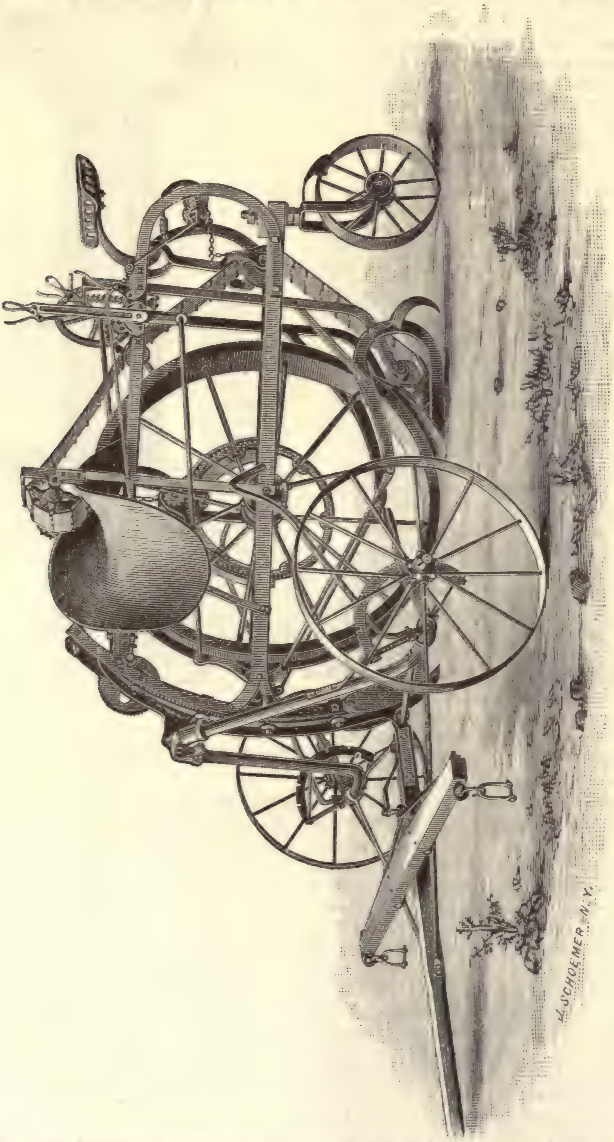


Fig. 2.—Potter's ditcher.

required depth. The cutting-wheel cuts down the sides of the ditch, and a scoop just behind the lowest part of the wheel pares off a layer of dirt, and causes it to pass upward under the control of an endless apron, which retains the earth in the grooved periphery of the wheel until the dirt is discharged upon a spout at the top and dumped on both sides of the ditch. The digging can be interrupted to maintain the grade of the ditch-bottom. The cutting-wheel frame is pivoted above its center of gravity, and maintains an upright position, cutting a perpendicular ditch at all times, whether the ground is level or inclines to either side. Small stones are readily thrown out, but large ones the machine rejects and passes over, scraping them bare of dirt, so that they may be reached and removed by other means.

Doffing: see Cotton-Spinning Machinery.

Dog: see Saws, Wood.

DOVETAILING-MACHINE. In the Knapp dovetailing-machine (Fig. 1) the work done is not strictly dovetailing in the sense of flaring-pins engaging any mortises of similar outline, but the general effect as regards utility is the same, and the work is more ornamental and more rapidly and easily done. The so-called dovetails that it makes for drawer fronts and sides are produced by working on the end of the front a series of semi-annular grooves, leaving standing in their centers a series of cylindrical tenons. The end of the drawer-side is worked away into a series of semicircular scallops, in the center of each of which there is a cylindrical hole; and the side being driven on to the front, pulling the latter away from the former is prevented by the cylindrical pins.

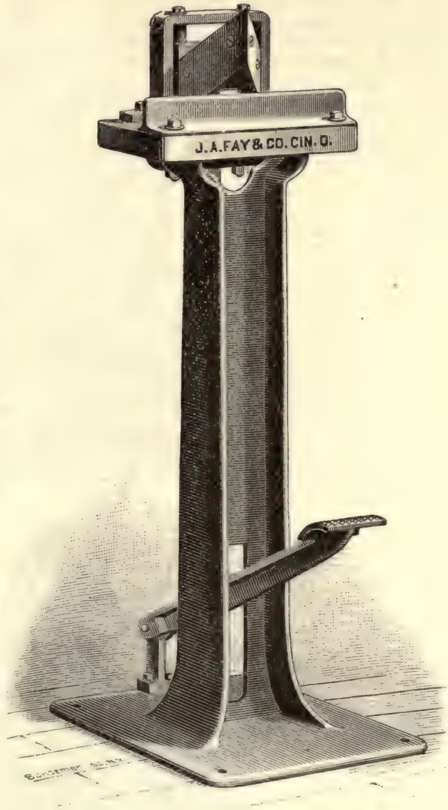


Fig. 1.—Dovetailing-machine.

Draft, Forced: see Engines, Marine.

Drawing Frame: see Cotton-Spinning Machines and Rope-Making Machines.
Rolls: see Rope-Making Machines.

DREDGES AND EXCAVATORS. I. Dredges. *Dredges at the Panama Canal.*—The dredges in use in the excavation of the Panama Canal are: (1) American Hercules dredges, (2) French dredges, (3) Belgian dredges, (4) Scotch dredges.

The Hercules dredge is of the endless chain of bucket type, using a high tower and long discharge-pipe. Practically the whole work of the machine is controlled by one man, who is stationed on the bow. A system of wheels at his hand connects with the different engines—namely, raising and lowering the lever, controlling the main engine and velocity of revolution of buckets, the gypsy-engine working the side-guys, the spuds also being raised and lowered by tackles on hoisting-drums. The digger may at a glance take in the situation, and use his governing wheels accordingly.

The machine consumes about 10 tons of coal per day. Its capacity is estimated as follows in cubic yards per day: Soft, sticky clay—buckets not fully emptying at upper tumbler—3,000 to 4,000; hard clay, 4,000; sand, 5,000, allowing one day of each week for repairs of machinery, and all days regarded as twenty-four working hours. The vibrations of the chain of buckets and links are reduced to a minimum when excavating in material not tenacious, allowing buckets to revolve 25 to 30 per minute. The dredges of iron-tower construction have done satisfactory work, and are lighter in tonnage and of less draft than those of wooden structure, and much more stiff.

Scotch dredges are self-propelling, having steamed out from Scotland to Colon and also to Panama, passing around the Horn. Their boilers are of 200 horse-power, and their horizontal engines communicate power to a crank-shaft on which is a sprocket-wheel, The upper tumbler-shaft has also a sprocket-wheel, and an endless chain communicates from the lower to the upper shaft, transmitting the motion. In heavy work these teeth break at frequent intervals. The ladder is in one section, requiring large construction of parts to gain the required strength for a long member. If in two sections, it might be lighter and require less power to raise and lower. This dredge is more adapted for deep-sea work than attacking new banks. It discharges into clapets, and is controlled by fore-and-aft guys and side-guys wound on friction-drums. Its draft is 7 to 8 ft., and it burns 6 tons of coal per 12 working hours. In ordinary work this dredge accomplishes 2,000 to 3,000 cubic metres per day of 12 hours.

The French dredge (Fig. 1) is the principal dredge in use along the line of the Panama Canal. There are different sizes, the one most in use being 100 ft. long by 30 ft. broad, and having a draft of 7 ft. of water. The hulls and entire machine are constructed of iron, in sections, in France, shipped to Colon, and transhipped at different points along the line where they are to be used. The cost is, approximately, $115,000 at Colon, not including cost of erection, which has been an expensive work at Panama, some engineers estimating the cost of erection at 35 per cent on original value. The tower is quite low, the elevation of hopper below upper tumbler being only 20 ft. above water-level. The ladder is in one section, supported upon axis in tower, and varies in length to the use of dredge in attacking new banks or in deepening channels. The buckets are of iron, wrought in one piece, the links being an integral part. The power is derived from a vertical engine, having three pistons, which act directly upward on a crank-shaft, which has a gear-wheel at either end, and large balance-

wheels. These gear-wheels connect through two other gear-wheels to the upper tumbler-shaft, thus giving a positive power, and when the machine is dredging in rock no slipping occurs, as in a belt connection. The engines are 180 horse-power in this sized dredge, and it forms a most powerful machine, so that in attacking hard-pan or loose rock it receives such a force as to accomplish its work when buckets and links do not break. In ordinary work in sand, gravel, clay, and loose material, a positive force is not necessary, as in rock-work. The large belt from a horizontal engine connecting with a gear attachment fitted with a tightener-pulley, increasing or diminishing the tension, has given good satisfaction, and controls the movements, except in rock-work.

The dimensions of a French dredge of large type are as follows: Length, 120 ft.; breadth, 28 ft.; depth, 10 ft.; draft, 7 ft.; depth of working, 28 ft.: sheer fore and aft, 10 in.; rise of deck, 6 in.; height of discharge above water-line, 20 ft.; height of top tumbler above water-line, 26 ft. 6 in.; width of bucket-well, 5 ft. 3 in.; frames, $4 \times 3 \times \frac{3}{8}$ in., 2 ft. apart, with re-

FIG. 1.—The French dredge.

verse angle-irons $3 \times 3 \times \frac{3}{8}$ in., in alternate frames; plating of bottom and bilges, near well, $\frac{7}{16}$ in.; plating otherwise, $\frac{3}{8}$ in.; plating of sides, $6\frac{3}{8}$ in.; plating of well, $\frac{3}{8}$ in.; deck-beams, bulb-iron, $8 \times \frac{3}{8}$ in., with double angle-irons $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in.: floors, 12×4 in.; angle-irons, $3 \times 3 \times \frac{3}{8}$ in.; length of bucket-ladder between centers, 64 ft. 6 in.; capacity of buckets, 16 cub. ft.; diameter of pins, $2\frac{7}{8}$ in.; high-pressure cylinders, 17 in. diameter by 24-in. stroke; low-pressure cylinders, 34 in. diameter by 24-in. stroke; air-pump, 10 in. diameter by 15-in. stroke; circulating pump, 10 in. diameter by 15-in. stroke; boiler diameter, 10 ft. 6 in.: boiler length, 9 ft. 6 in.; boiler heating-surface, 900 sq. ft.; boiler working-pressure, 80 lbs. per sq. in.; cost at Colon, $115,000.

One of these machines of large type has done valuable work at the Mindi Cut, near Gatun, on the Panama Canal, in broken rock, stiff clay, and hard-pan. The material excavated in buckets is carried up into a hopper, discharged with water, pumped up hydraulically sufficiently to discharge it into self-dumping steam-clapets alongside. The capacity of these dredges is variable in the extreme, no one machine having done a large amount of satisfactory work. A fair estimate is 200 to 250 yards per hour for 12 working hours.

The Belgian dredge is quite similar to the French dredge, deriving its power in like manner by sprocket and chain connection. It is of 200 horse-power, has three horizontal return tubular boilers, and two horizontal engines, the pistons of which connect with a crank-shaft, on which is a wheel. It discharges on each side into clapets. The velocity of the buckets is 20 to 30 per minute; contents, $\frac{1}{3}$ cubic metre.

Dredging Operations in New York Harbor have been actively carried on in order to improve the channels leading from the ocean. The fleet of vessels employed by the contractors comprises three propellers, each fitted with two Edwards centrifugal pumps and two dredging-scoops connected by pipes with the pumps. Each vessel (Fig. 2) is divided by bulkheads into tanks for the reception of the dredged material. In the bottom of each of the tanks are valves, worked by horizontal valve-wheels. By proper conduits the dredged material can be delivered to any one of the tanks, according to the way in which the chutes are set.

The estimated capacity of the plants per working-day are: No. 1, 2,000 cub. yds.; No. 2, 1,500 cub. yds.: No. 3, 3,000 cub. ds.; giving a total capacity of 6,500 cub. yds. All the material is taken outside of Scotland Lightship and dumped at a distance of about 8 miles from the

main ship-channel, and 5 miles from Gedney's Channel, in not less than 14 fathoms of water.

The general operation is as follows: The scoop (Fig. 3) is dropped down to the bottom, on which it runs upon wheels. The pipe which connects it to its pump is of steel, containing a ball-and-socket joint, and including a short length of heavy India-rubber pipe re-enforced with steel bands, in order to prevent breakage when the vessel is rolling or pitching in a sea-way. By means of a steam-jet connected with the top of the centrifugal pump, a vacuum is produced within the pump and pipe, under the effects of which vacuum water rises through the pipes until the pump-chamber is completely filled. Then, on starting the pump and opening the outlet-valve hitherto closed, it at once begins to draw up material. At the upper surface of the scoop, a foot or so above the bottom of the water, a water-valve is arranged which may be opened or closed by means of a small rope or lanyard. This is done from the deck of the propeller, and regulates the proportions of water and solid material. The operative can tell by the sound of the pump whether it is receiving too much or too little solid material, and sets the valve accordingly.

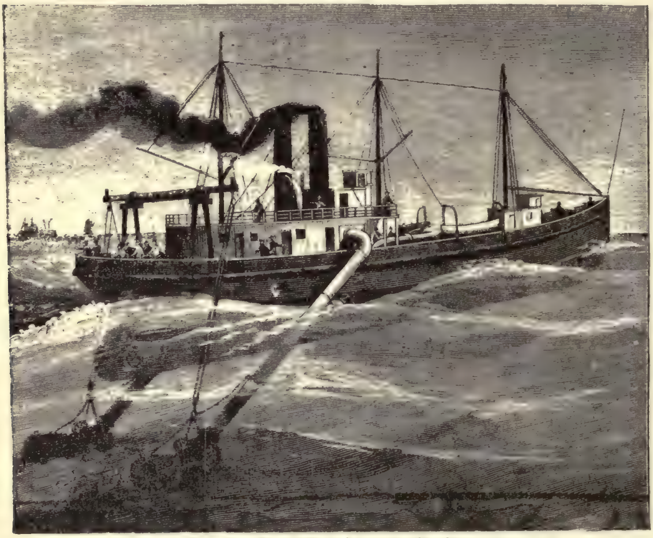


FIG. 2.—Centrifugal-pump dredge.

In dredging, the boat is made to advance at the rate of from ½ to 2 miles an hour, while both pumps are driven as fast as may be. It is very important to drive them to their full capacity, as they possess a critical speed below which their efficiency is greatly reduced. The boat thus travels down the channel, dragging with it the scoops, which are continually raking up the ground, which, as fast as it is loosened, is drawn up through the pipes by the pumps. The suctions are attached to the side of the boat about midship, so that they are unaffected by pitching, while, owing to the great width of the boat, its rolling is so slight that they are not thereby disturbed.

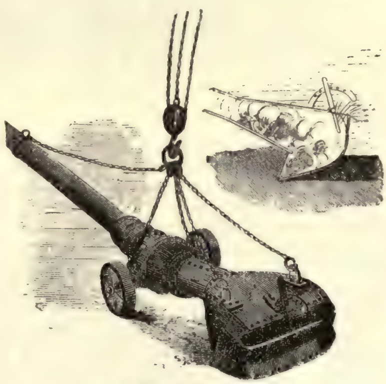


FIG. 3.—Dredge-scoop.

Dredging at Suez.—The Kobnitz Rock-Breaking Dredge (Fig. 4) operates by letting fall a heavy, suitably shaped mass on the surface of the rock, which shatters it as artillery-fire demolishes the stone walls of a fortress.

The Dérocheuse represented in the engraving has done important work in the enlargement of the Suez Canal. The hull of this rock-cutting dredger is 180 ft. long by 40 ft. broad and 12 ft. deep; the mean draft is 9 ft., and there are 18 water-tight compartments. Five steel-pointed rock-cutting rams, each weighing 4 tons, are arranged in line on each side of the central well, through which the buckets lift the crushed rock. Hydraulic power raises them to a height of from 5 to 20 ft., and they are then let fall on the rock. These rams can work on each side of the lower tumbler, or they can be moved by steam-power, either forward or aft, to suit the position of the dredging-gear or the requirements of the work. With the set of hydraulic levers placed below the steam-crane, between 200 and 300 blows per hour can be delivered with one set of five cutters. Combined with the rock-cutting apparatus, dredging machinery, specially adapted for lifting broken rock, is provided. A guide-wheel is fitted, which supports the sag of the bucket-chain when wear has taken place, and relieves the strain on the bearings and pins. With this guide-wheel or relieving-drum, the maximum dredging depth of the machine is 40 ft.; without it more than 30 ft. would not be attained.

For driving the bucket-chain there is a four-cylinder two-crank compound engine of 200 indicated horse-power, which by special friction-gear works two steel pitch-chains passing

round pitch-wheels connected to the upper tumbler. If the buckets catch on solid rock, the friction-gear slips until the undue strain is relieved.

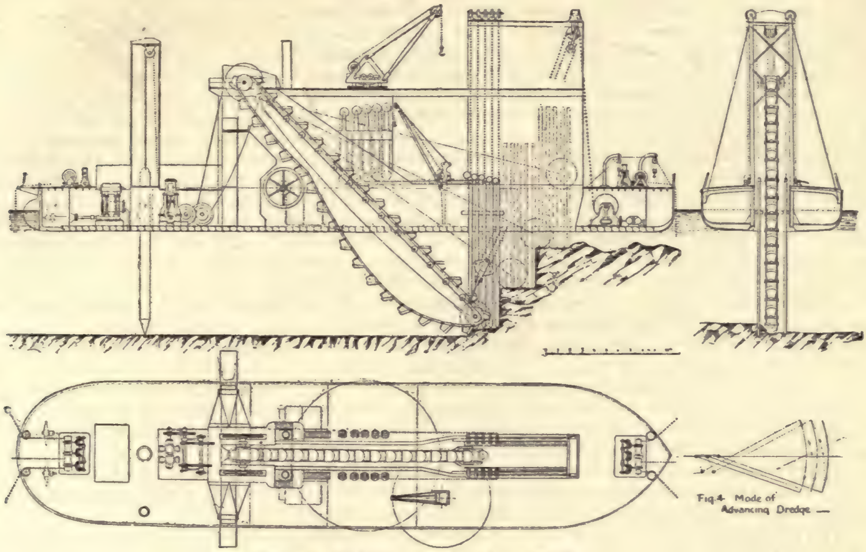


FIG. 4.—Kobnitz rock-breaking dredge.

While at work, the vessel is moved over the surface in a series of arcs, by independent winch-motion arranged for swinging the vessel from side to side, pivoting on a steel mooring-pile, which goes down through the hull in the after part of the machine.

A careful record of the working of this machine was kept during 16 days of September, 1888, with the following results: Amount of pure rock extracted, 1,000 cub. yds.; tons of clay extracted, 249; number of hours of work, 111; wages of crew at $2.76 per hour, 140 hours, $387; cost of coal at $7.29 per ton, $153; oil and stores, fresh water, sundries, etc., $92; total expenses for 1,000 cub. yds., $632; cost per cub. yd. of pure rock, 63·2 cts. Although the 1,000 cub. yds. of hard rock were excavated at a cost of 63 cts. per cub. yd., it would be quite wrong to treat this figure as a basis for continuous working, for at the end of a year's work many parts of the dredger would be worn, and the repairs required each year would probably double the cost per cub. yd. excavated. Thus, the probable cost per cub. yd. would be about $1.20 for a machine similar to the Dérocheuse, which could remove about 20,000 cub. yds. of average rock in a year, at a cost of about $24,000 per annum. This estimate does not include the transport of the broken rock in barges, nor the depreciation, interest, and insurance of the plant.

The Jandin Hydro-Pneumatic Dredger is a dredger of a new system combined with a forcing and conveying apparatus carried upon a raft 1,000 ft. in length. It was devised by M. Jandin, an engineer of Lyons, for excavating a canal 20 ft. in depth, from the city of Uleaborg, Finland, to the Gulf of Bothnia, in the mouth of the river Ulea, where the depth of water has been reduced to about 13 ft. by accumulations of sand.

The apparatus consists of a hydro-pneumatic dredging-pipe, which raises the mixture of water and excavated material, and empties it into a large cylindrical reservoir, which constitutes the forcing apparatus. The dredging-pipe, the orifice of which rests constantly upon the bottom, forms the axis of a rigid frame, which is guided vertically by the sides of a well at the extremity of the boat. Its upper part is connected with a horizontal pipe, which enters the reservoir through a flexible elbow. Near the lower orifice of the dredging-pipe there is arranged an annular injector, which introduces compressed air upwardly into the pipe. This injection of air produces a suction, while, at the same time, it forms in the pipe a mixture of air, water, and material carried along by the water, a mixture whose density is less than that of the water. It is easily conceived that, with a given depth of water, it is possible, with the coefficients furnished by experiment, to calculate the volume of air necessary to make the external charge upon the orifice greater than the weight of the column of the mixture ascending above the level of the water to a fixed height. The principal advantage of this system is that there is no obstruction possible, as the orifice presents a passage that is smaller than the constant section of the pipe, and no parts in motion are in contact with the excavated material. In this way there are avoided two of the inconveniences of pumps applied to dredging, and which cause frequent stoppages and necessitate costly repairs.

Jets of compressed air, arranged around the orifice and directed against the earth, disintegrate the latter, and increase the proportion of the material carried along by the velocity of the water—a proportion which, in ordinary depths of 20 or 25 ft., reaches, as regards sand, 25 per cent of the volume of water.

At the spot where work is being carried on upon the pneumatic foundations of the Morand bridge upon the Rhône, where a dredger of this system is employed, it dredged in 38 ft. of water a bundle of chains 1¼ in. in diameter and weighing 110 lbs., the height it was raised above water being about 10 ft. This apparatus, which is 10 in. in diameter, is actuated by a compressor, which takes in 6,100 cub. in. of air per sec., and is situated at 150 yds. from the pier where the dredging is going on. The forcing apparatus, which is a cylindrical reservoir 10 ft. in diameter and 22 in length, with convex ends, and having a capacity of 176 cub. ft., receives the mixture of water and material. The air escapes through an opening above surmounted by an open dome, upon the side of which there is a waste-pipe. When the reservoir is full, and the water is making its escape through the waste-pipe, a single external lever, manœuvred by the chief dredgeman, closes valves that in turn close internally the orifice of the dredging-pipe, and open the air-port, and at the same time reverse, through three-way cocks, a current of compressed air, which is then forced through distinct pipes into the reservoir, and led to injection-tubes, properly spaced, in the lower part of the reservoir. The effect of the jets of compressed air, formed under the mass of earth and water, is to lift the material while mixing it with water and throwing it toward the orifice situated at the lowest point of the excavation. The total time taken to force to a distance of 1,000 ft. is 6 min., 2 of which are consumed in the passage through the conduit. The end of the tubing is worked by the escape, at the end of the conduit, of a wheat-sheaf jet of water and air projected through an explosion to 48 ft. from the orifice, the conduit remaining empty and being cleaned out by this final action of the air. At the same time, the automatic valve that closes the upper orifice of the reservoir opens by its own weight. The lever that works the cocks is then reversed, and the air is sent to the dredging-pipe, and another filling at once occurs. Thus the dredging and forcing occur successively by periods of from 5 to 6 min., the boat remaining immovable during the forcing period.

The Vernaudon Suction-Dredge consists essentially of a dredging-pipe which lifts the material, and in front of which operates a shaft armed with knives. The pipe is connected with a centrifugal pump, which forces the material into floating pipes.

The dredging-pipe, which is 16 in. in diameter, is arranged in a well 35 ft. in length, and established in the axis of the dredger. It is connected with the conduit that leads to the pump by a hinge-joint, and the conduit is provided with an aperture through which a workman can quickly, and without stopping the pump, extract too large pieces of excavated material or stones that might damage the pump-buckets. At its other extremity the pipe is provided with a box that carries a frame cast in a piece with it, and in which are arranged the bearings of the knife-shaft. As the pipe has to dredge at variable depths, it is capable of being lifted by means of a double-frame established on the two sides of the well, and the windlasses of which are actuated directly by a small motor. In order to secure the rigidity necessary during operations, the pipe is guided by a frame which consists of uprights connected by cross-braces, and which moves in a slide placed between the uprights of the double frame. When the apparatus is not working, the pipe and frame are raised. In order to regulate the admission of water into the pipe, the latter is provided with three slide-valves, each sliding upon the same plate, containing rectangular orifices. These valves are actuated by hand through a shaft parallel with the pipe, and which, through a screw-thread, actuates the nuts fixed to the valves.

The disintegrating apparatus has to be modified according to the ground operated upon. In argillaceous sand and sticky clay, a shaft armed with a double set of knives is used. These knives, which are solidly keyed to a box, are helicoidal in form, and the spirals run in opposite directions, so as to bring the material that they detach toward the orifice of the pipe. In compact earth, where no caving in is to be feared, the knife-shaft is arranged at the extremity of the pipe. In muddy sand, it is well to establish the shaft at a certain distance behind the orifice. The knife-shaft receives its motion, through bevel-wheels, from another shaft parallel with the axis of the dredge-pipe, and resting upon it through the intermedium of pillow-blocks. This shaft is actuated by the principal motor through bevel-wheels. The centrifugal pump is placed above the float water-line. The result of this arrangement is that the power necessary for suction depends in practice only upon the difference in density between the surrounding water and the column of liquid charged with earth, which rises in the pipe, thus permitting of dredging to variable depths without sensible increase of motive power. The excavated matter passes through the pump and is forced into the floating pipes. These are of iron plate, with flexible joints. The engine is of 120 horse-power.

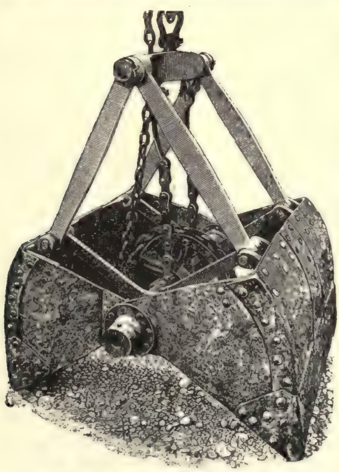


FIG. 5.—Morgan grab-bucket.

The Morgan Grab-Dredger Bucket, represented in Fig. 5, is employed in the dredging of the Mersey dock at Liverpool in all dipper-dredgers. It is worked by two chains passing over the jib-head of the crane. The lifting-chain is shackled to a large cam-shaped ring or eccentric fixed on a sleeve, which turns loosely on a shaft passing along the

apex of the bucket from one end to the other; to the same sleeve are fixed two smaller eccentrics, one on each side of the center, and to these are attached chains of fixed length, made fast to an upper cross-head, from which connecting-rods pass to the top edges of the sides of the bucket. The opening chain is attached to the cross-head referred to. When the bucket is open the lifting-chain lies wound round the large eccentric. The closing is effected by hauling on the lifting-chain, thereby winding in the chains on the small eccentrics, and so pulling down the cross-head, the connecting-rods from which force the sides of the bucket together. The bucket opens when the opening-chain is held, and the lifting-chain let go. The central shaft then lowers away from the cross-head, and the sides of the bucket expand, until the short chains between the latter and the small eccentrics are fully unwound; at the same time a certain length of the slack of the lifting-chain becomes wound on the large eccentric. The eccentrics on the shaft are so arranged as to give a large power toward closing the bucket at the commencement of closing, it being then desirable that it should dig into the silt. Radius-rods are put in from the central shaft to the top of the sides, where the thrust of the closing-rods is applied. This arrangement maintains the sides in shape and allows of their being made very light. To reduce weight also the central shaft is made hollow. The bucket illustrated will clear a space of about 30 sq. ft., and will raise from 30 cwt. to 40 cwt. of stuff per lift. Fig. 5 is prepared from a photograph of one of these buckets, which has dredged over half a million tons of silt, and at present is in good condition.

II. Excavators.—Many varieties of bucket-elevators, using endless chains of buckets, are in use in the construction of the Panama Canal (for full description, see Plant and Materials of the Panama Canal, by W. P. Williams, *Trans. A. S. C. E.*, July, 1888).

The operation of the so-called "down-digger" is described as follows: The machine is constructed on two trucks of four wheels each, and of a 5-ft. gauge. When in working condition, the base is broadened by jacking up and throwing the weight on the working side out to a third rail, 7 ft. distant from the line-rail. The ladder over which the buckets travel is hung on an axis on the back of the machine, but throws the center of gravity toward the working side, and, to offset this, ballast of railroad-iron is loaded on the extension on the back of the machine. The boilers are usually horizontal, giving a low center of gravity, and the water-tank of iron and a coal-bunker of iron are placed on the boiler-end of the platform. The endless chain of buckets is operated on the "over-and-under" system. The buckets are made with a quadrangular hemispherical face and no back. The links are hung at the rear of the buckets. The ladder is suspended down the bank, and is raised or lowered to give a slight contact to the cutting nose of the bucket. The latter becomes filled by gradually cut-

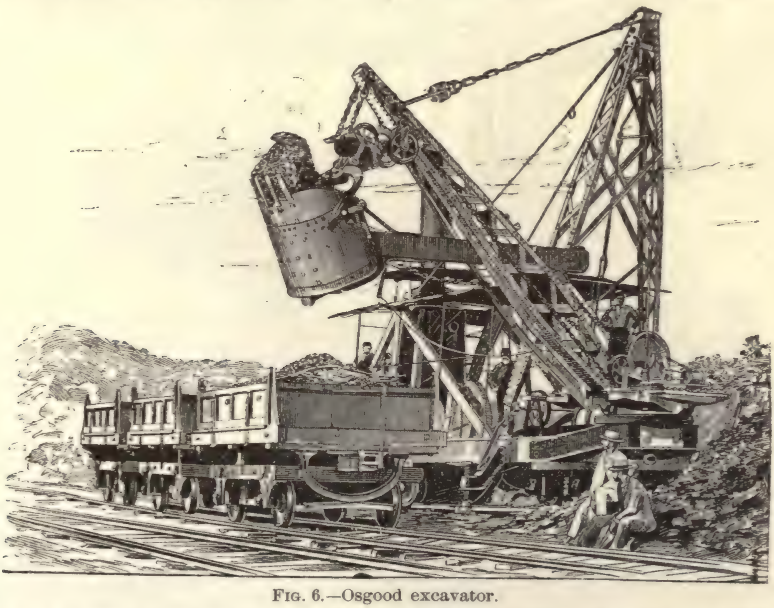


Fig. 6.—Osgood excavator.

ting a slice all the way up the bank. As it pauses over the upper tumbler, the contents fall into a hopper, and thence through a chute into a dump-car on the second track, and back of the machine. The engineer of the excavator controls its movements entirely, raising and lowering the ladder, also moving the excavator up and down the track by an endless belt running from a sprocket-wheel on the crank-shaft of the engine to a sprocket-wheel on the car-axle. In the "up-digger," the buckets have an "under-and-over" movement.

The Osgood Excavator (represented in Fig. 6) is supported on two trucks of 5-ft. gauge, and, when in position for working, the forward truck of the machine is jacked up, throwing the weight off the rails, and the outriggers of 8-ft. centers are used instead, giving a wider

working base. The weight of these large type of machines is about 30 tons. Self-propulsion is gained by an endless-belt connection with the main engine-shaft to the rear axles. Water-tank and coal-tank are placed on the rear car near the boiler. These machines will excavate a cut up to 70 ft. in width, and dump contents of dipper 29 ft. above track. The mode of action is for the excavator to start at the face of the cut and gradually excavate forward and on each side of sufficient width for the placing of two tracks, one on each side of the excavator, which may move forward in reaches of 8 ft., each digging her own track. Dump-cars are brought in alongside on either track from the rear switches by cable connection winding around a drum on the exterior of the body of the excavator. These cars when filled are hauled out on to the main line, and empty cars are in readiness to supply their places. The dipper delivers first on one side, then on the other, the cars being constantly supplied. In sand and loose gravel, as much as 2,000 yds. per day of ten hours have been excavated.

DRILLING-MACHINES, METAL. *Universal Radial Drill.*—Fig. 1 represents a universal radial drill built by the Niles Tool Works, Hamilton, Ohio. A heavy, rotating column, mounted upon a long supporting sleeve, which is secured to the base-plate, carries a radial arm, which can be clamped in any position. The machine is driven from an overhead counter-shaft operated by bevel-gearing, and by a central spur-gear seen at the top of the column. This also communicates motion through tumbler-gearing to the screw, which is operated to raise and lower the arm by power. Motion is communicated to the drill-spindle from the cone, which is strongly back-geared by means of spur-gears, a splined shaft, and bevel-gear-

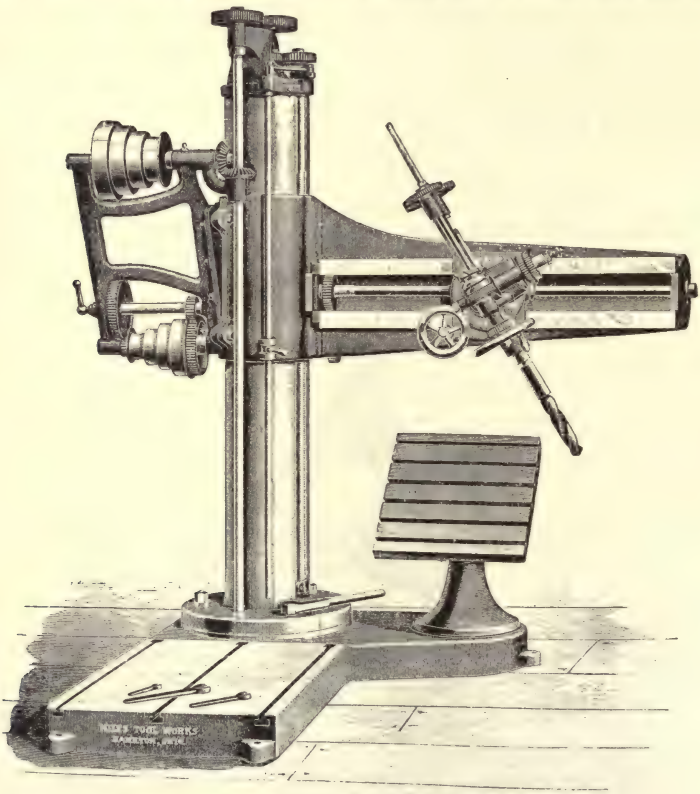


Fig. 1.—Universal radial drill.

ing. The arm is in form similar to a box-girder, and is in one piece. The drill-head is securely gibbed upon the arm, and is adjustable to any position thereon. It is also adjustable to any angular position upon its saddle.

Sensitive Drill.—Fig. 2 represents a sensitive drill manufactured by W. F. & J. Barnes, Rockford, Ill. By the friction-disk, shown in the cut, the speed of the drill-spindle can be increased or diminished, or the motion reversed, without stopping the machine or shifting belts. The feed-lever is provided with a sensitive adjustment, which makes it possible to use the smallest drills. The platen can be moved on the column, and clamped at any desired height.

Multiple Traverse Table-Drill.—This machine, shown in Fig. 3, is built by the Niles Tool Works, and is similar in design to the usual pattern of multiple drill, except that it is provided with a table arranged to slide upon the bed. Machines of this class are especially desirable when it is required to drill a number of holes in heavy pieces clamped together, such

FIG. 2.—Sensitive drill.

as vault-doors, etc. In work of this kind the separate pieces can be fastened together upon the table and any desired part brought under the drills. The spindles have 12-in. travel, and each has independent power-feed with three changes. They are also arranged for hand-feed, and each is counterweighted and has quick return. The machine is capable of drilling three 1½-in. holes or two 2-in. holes at the same time through steel plate.

Ball-Bearings for Drill-Presses.—Fig. 4 shows a ball-bearing used to overcome the friction of the collar of the spindle of a drill-press. It consists of two collars, one having a flange fitting into a rabbet turned on the corner of the other, to prevent dirt from getting in from the outside, both the collars being provided with a half-round groove turned on their face, in which the balls revolve. The collars, as well as the balls, are made of fine steel. (See also BEARINGS, BALL.)

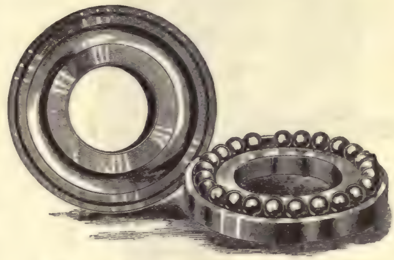


FIG. 4.—Ball-bearings for drill-presses.

Leeds' Horizontal and Radial Drill.—This machine (Fig. 5) is designed to work on or from a drill-press, and is driven direct from the drill-press spindle. It is a substitute for the hand-ratchet, and is useful in drilling the ends and diagonal parts of frames; it can also be mounted on the work and driven by a sliding-shaft and universal joints. Drilling in all directions can be done, with the two taper-shanks and the horizontal and vertical movements, by loosening the nuts shown.

Power consumed in Drilling.—A study of the power required to drive an ordinary drill-press has been made by Prof. Lester P. Breckenridge, M. E., of Lehigh University. Indicator

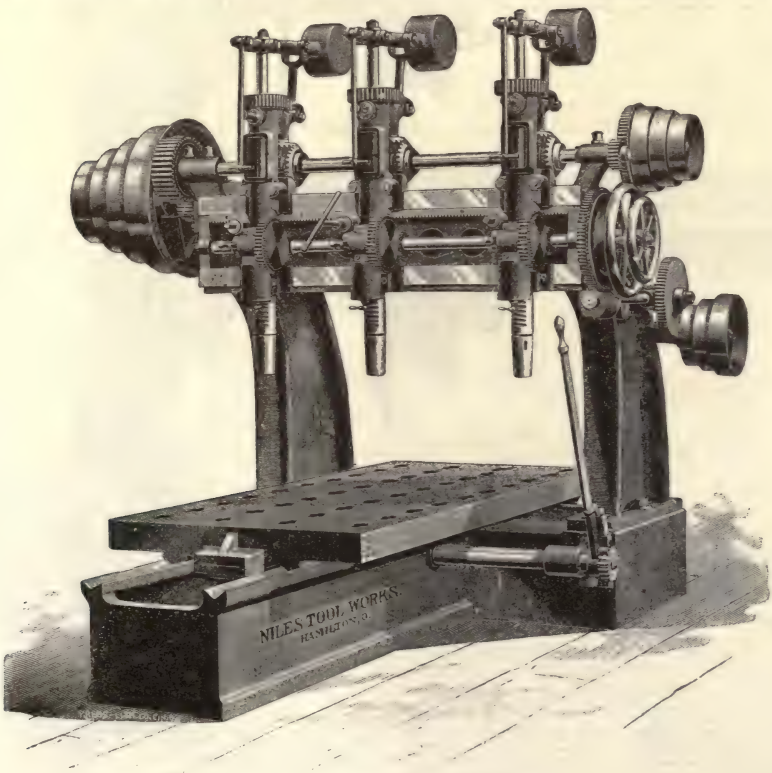


FIG. 3.—Multiple traverse table-drill.

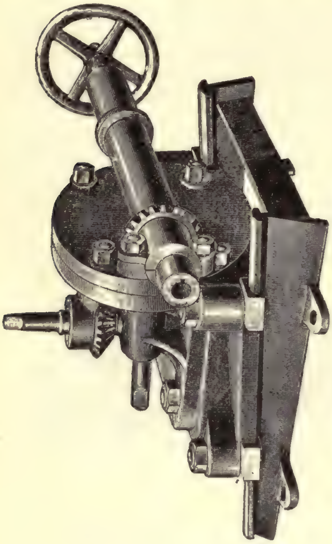


FIG. 5.—Horizontal and radial drill.

FIG. 6.—Test of power consumed in drilling.

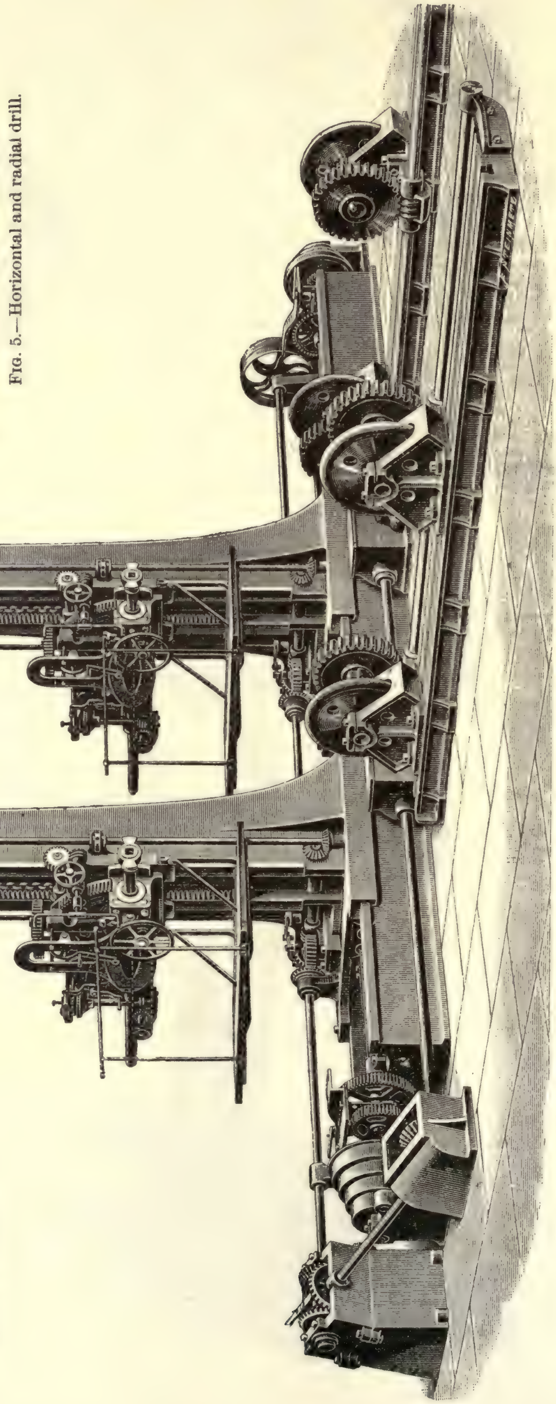


FIG. 7.—Drilling-machine for boiler stayholes.

cards were taken from an apparatus, as shown in Fig. 6, consisting of a cylinder of cast-iron, with flange at the base, and bored out to receive a plunger. The area of this cylinder was 10 sq. in. Near the bottom of the plunger three grooves $\frac{3}{32}$ in. deep were cut, and about $\frac{1}{2}$ in. apart, in order to prevent leakage of oil, which was placed in the cylinder below the plunger. Communication with oil was then made to a steam-gauge on one side and an indicator on the other, as shown. The details taken are shown in the subjoined table, by means of which an accurate calculation may be made at any time as to capacity and time required to do a given piece of work with a given speed of drill:

Diameter of drill.	Depth of hole drilled.	SHORTEST TIME REQUIRED TO DRILL WHEN FEEDING. By power.		By hand.		Maximum pressure on drill while drilling at start.	Maximum pressure on drill when working with full diameter of drill.
Inch.	Inch.	Min.	sec.	Min.	sec.	Pounds.	Pounds.
¼	½	0	16	0	14	400	350 to 400
¼	1	0	32	0	21		
½	½	0	32	0	29	900	800 to 900
½	1	0	30	0	45		
¾	½	0	42	0	38	1,100	800 to 900
¾	1	1	20	1	06		
1	½	0	47	0	48	1,450	1,000 to 1,150
1	1	1	32	1	47		
1¼	½	..	..	1	42	1,800	1,000 to 1,150
1¼	1	3	24	3	10		

Drilling-Machine for Boiler Stayholes.—Fig. 7 represents a drilling-machine built by Thomas Shanks & Co., Johnstone, Scotland, for drilling and tapping the holes for screwed stays in boiler shells and backs. There are two drills carried by separate standards, each having a traverse of 20 ft. The vertical range is 10 ft. The spindle may be set at an angle of 25°. The bed is 4 ft. 6 in. wide. In the driving headstock are four speed-cones and two purchases of gearing for light or heavy work, instantly interchangeable by levers. The standard is moved by a grooved driving-shaft with fast and loose pulleys, and the reversing motion is by bevel-gear and clutches worked by hand. The vertical driving-shaft has strong bevel-gear and clutches to stand the tear and wear of reversing, and connects by the driving-gear to a spindle 3½ in. in diameter. Two bevel-wheels—one fine and the other coarse pitch—are keyed on the revolving tube carrying the spindle. Quick motion is obtained through direct gear and slow motion by spur-wheel and pinion. The drill-carriage is balanced and its level is alterable at will. There is a second standard in the machine, with a horizontal driving-shaft in the bed parallel to the other. Revolving cradles are placed in front of the machine, and these are not only adjustable for different diameters and lengths of boilers, but also in such a manner as to support a boiler with either its back or its side toward the drills, as may be required. When used for the latter purpose, the cradles can be revolved by power, so as to bring a new part of the shell within range of the machine. (See *Engineering*, Oct. 24, 1890.)

Portable Hydraulic Drilling-Machine.—Fig. 8 represents a portable hydraulic drilling-machine designed by M. Berriere Fontaine, of Toulon, France, and used in the Toulon dock-yard. Such machines are capable of drilling in their place, and after erection, nearly all the holes required for rivets, bolts, etc., in all kinds of iron or steel structures—such as ships, bridges, girders, and boilers—wherever hydraulic pressure is available for working them. By drilling in place, a single operation serves to drill through all the superposed thickness without stopping the tool; whereas, when the pieces are separate, as in the shop, as many separate drilling operations are required as there are pieces.

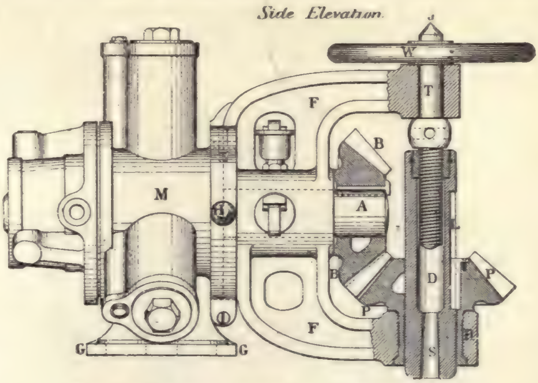


Fig. 8.—Portable hydraulic drilling-machine.

Each drilling-machine is composed of two parts: First, a small hydraulic motor *M*, driven by water pressure supplied from a main through flexible or jointed pipes. The discharge water is led away through India-rubber tubing. The motors are Brotherhood's three-cylinder engines. Second, a drill-holder, consisting of a small frame *F* of C-shape, in which are arranged the bearings of the driving-shaft *A* from the motor, and of the hollow drill-spindle *D* at right angles to it. On the motor-shaft *A* is keyed a bevel-wheel *B*, gearing with a bevel-pinion *P* on the drill-spindle *D*. At one end of the drill-spindle is a socket *S* for holding, and the other end is threaded internally for receiving the setting-up screw *T*, which is turned by the hand-wheel *W*, either to give the feed while drilling or to withdraw the drill when the hole is finished. A longitudinal slot *L* for the key of the bevel-pinion *P* allows

the drill-spindle to slide through the pinion while the latter is kept in place by an annular recess *R*. Beyond the hand-wheel *W* the screw *T* terminates in a point *J*, which can be pressed against a cross-piece or frame, such as is used for drilling with a ratchet-brace. The central part of the frame *F* is bolted to the flange of the motor *M*, and thus forms a long bearing for the shaft *A*; and small closed lubricators insure the bearing being properly oiled, in whatever position the drill may be held. In the base *G* of the motor are slotted holes for fixing it to the structure. These machines are made of steel and phosphor bronze. The weight does not exceed 105 lbs. for the 1 horse-power drill and 62 lbs. for the ½ horse-power drill. Trials made for a lengthened period have proved that, in the case of a large armor-clad man-of-war, built on the cellular system, and consequently of very complicated design, the number of holes drilled in place by these small hydraulic machines is at least 25 per cent greater than the number of similar holes that can be drilled in the same time by stationary machines in the shops, and is at least six or seven times greater than the number of similar holes that can be drilled in place by ratchet-braces. In the 1 horse-power machine the motor makes 90 revolutions per minute. It drills holes from 1⅝ up to 2 in. diameter. The ½ horse-power machines make 150 revolutions per minute and drill holes up to 1¼ in. diameter.

Drill: see Coal-Mining Machines, Grinding Machines, Seeders and Drills, and Watches and Clocks.

DRILLS, ROCK. I. Drills driven by Steam or Air.—*The Sergeant Tappet-Drill.*—This machine has a positive valve, moved by direct contact with the piston. It is used in quarry-work where the steam is wet, and where the rock is reasonably soft, such as slate, sandstone, oolitic limestone, etc. The valve is of rocker form, and is moved by shoulders on the piston. The valve and rocker are in one piece.

The Rand Drill Co.'s "Slugger" Rock-Drill.—In the invention and design of this machine the object was to obtain a better steam distribution than had before prevailed in machines of this class. The chief resulting differences between this machine and others are as follows:

1. In the so-called "tappet" machines the motion of the piston is arrested at the conclusion of the return or inboard stroke by a live-steam cushion, obtained by giving the valve a great degree of "lead." In this machine the piston is stopped (so far as is possible so to do) by an exhaust-steam cushion, obtained by closing the exhaust port soon after the return stroke has commenced, and the steam thus compressed forms a portion of that used to effect the succeeding striking stroke. 2. In "tappet" machines the steam is used without expansion. In this machine expansion is introduced to any desired extent. 3. "Tappet" machines strike a cushioned blow. This machine strikes an uncushioned blow.

The cushioned blow is a necessity with "tappet"-valve gears—this necessity arising from the following circumstances: The length of stroke of a rock-drill is not constant. As the drill hole progresses in depth the cylinder must be correspondingly fed forward, but to effect this feed with perfect regularity is found to be an impossibility. The effect of this irregular feed of the cylinder is to vary the point marking the end of the stroke of the piston—the approach of the piston to the lower cylinder-head varying from stroke to stroke. Moreover, in starting a hole, and under certain circumstances, it is occasionally desirable to be able to feed the cylinder forward, so as to shorten the stroke still more than is actually necessary to accommodate the usual irregularity of feed. In brief, the machine must be able to take strokes of considerably less than normal length without failure; to trip its valve, in order to continue in uninterrupted action. This circumstance has usually been provided for by simply giving the valve a great degree of lead at the *lower* end of the cylinder, tripping the valve at a point previously decided upon as the end of the shortest stroke to be allowed, and then submitting from necessity to the loss of power due to the cushion thus introduced into all strokes of usual

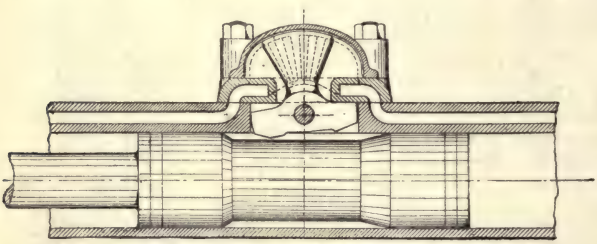


Fig. 1.—Steam drill—valve motion.

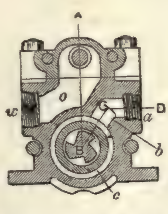


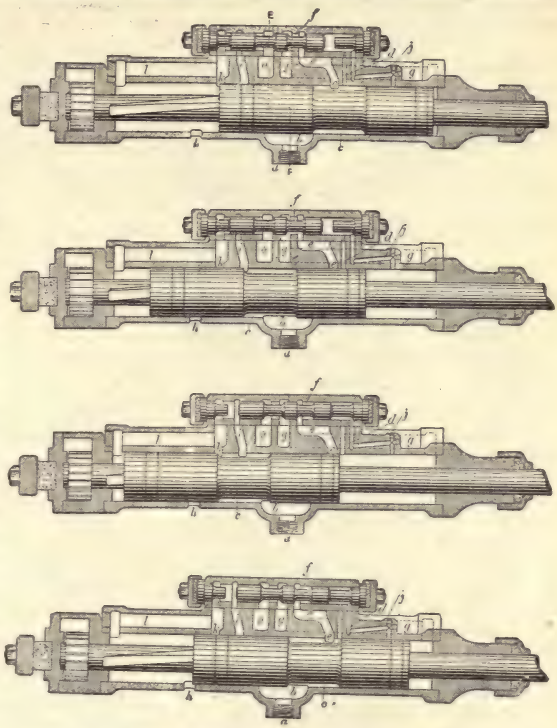
Fig. 2.—Cross section.

length. In the machine about to be described, provision has been made for this irregular feed and length of stroke, but nevertheless, when full-length strokes are made, the valve does not move, nor is steam admitted below the piston, until the actual delivery of the blow.

Figs. 3, 4, 5, and 6 are longitudinal sections taken on the broken line *A B C D* of Fig. 2, the piston and valve being shown in a number of successive positions. Fig. 2 is a cross-section on the line *E F* of Fig. 3.

In Fig. 3 the piston has just completed its striking stroke and is ready to commence its return stroke. The steam which effected the preceding striking stroke has been exhausted through the opening *h*, which forms the only exhaust port for the upper or left-hand end of the cylinder. Steam enters at the supply nozzle *a*, flows through the longitudinal groove *b* in

the cylinder (seen also in Fig. 2) to the broad, shallow circumferential groove *c* in the piston. The longitudinal groove *b* is of such length as to maintain constant communication between the nozzle *a* and the circumferential groove *c*. Its office is to lessen the otherwise inconvenient length of the circumferential groove *c*. This in turn diminishes the length of piston and cylinder, and hence weight of machine. This circumferential groove *c* forms, in effect, the steam-chest of the machine, and from it the steam is distributed alternately to the opposite ends of the cylinder. Through the passage *d* steam pressure is maintained in the lower end of the valve-chest, firmly holding the valve in the position shown. Steam flows through the passage *e e*, and from this through the neck *f* of the valve to the passage *g g*, which in turn leads it to the lower end of the cylinder. The piston now starts upward, and presently takes the position shown in Fig. 4. In passing from the position of Fig. 3 to that of Fig. 4, the piston has closed the ports *d e h* and opened *i j*. Closing *h* confines the exhaust steam in the upper end of the cylinder, forming an exhaust cushion before the piston, and accomplishes the first improvement named above. Closing *d* merely isolates the steam already in the end of the valve-chest. Closing *e* cuts off the supply of steam to the lower end of the cylinder, and for that end effects the second improvement aimed at. Opening *i* has no effect, as its upper end is still closed by the valve. Opening *j* establishes communication between the lower ends of cylinder and valve-chest, and hence, as expansion goes on from the cut-off, the pressure acting on the end of the *valve* will gradually fall. In Fig. 5 the piston has ascended still farther, and uncovered the port *k*, admitting steam through the passages *l* and *n*, respectively, to the upper end of the cylinder and valve-chest. The former completes the work of stopping the motion of the piston; the latter, being opposed only by expanded steam at the lower end of the valve, as just explained, shifts the valve downward, thus establishing communication between the port *g g* and the exhaust passage *o*. The piston now commences its descent, and closes and opens the various ports in the reverse order to that just explained. Closing *k* has no effect, as *i* being now open, the steam can pass through it to the upper end of the cylinder. Closing *i* effects the cut-off for the upper end of the cylinder, exactly as closing *e* did for the lower end. Opening *e* has no effect, its upper end being now closed by the valve. Opening *h* effects the exhaust. In the actual machine a covered passage leads the exhaust steam from the port *h* to the passage *o*, so that the exhaust from the two ends of the cylinder escapes to the air through a single outlet *w* of Fig. 2. In Fig. 6 the piston has just uncovered the port *d* leading to the lower end of the valve-chest, and it has thus established the conditions which will reverse the valve and insure the next upward stroke. As the port *d* is just uncovered, and no more, the piston is at the point marking the termination of its shortest working stroke. Should the piston stop short of the position shown (by reason of excessive feed), the port *d* would not be uncovered, the valve would not reverse, and the machine would stop. As will be seen, the piston is at some distance from the lower cylinder-head, this distance representing the latitude of irregularity permitted in the feed. The piston may stop anywhere between the end of the cylinder and the position of Fig. 6, and the action will continue. In order to effect the third improvement (the uncushioned blow), it is necessary to provide an arrangement which, notwithstanding the passage *d* is always opened at the position shown in Fig. 6, shall yet, when full-length strokes are made, permit the piston to pass on and complete its stroke without the movement of the valve actually taking place until the delivery of the blow. This is effected by simply constricting a portion of this passage *d*, making it of such small size that the passage through it of the steam necessary to move the valve shall be delayed until the piston has had time to pass on and complete its stroke. In the machine as actually made, most of the ports opening into the cylinder are arranged in pairs, and diametrically opposite one another, to obviate side pressure on the piston.



FIGS. 3-6.—Longitudinal section showing valve in different positions.

In Fig. 7 are shown indicator diagrams taken with the machine operated by compressed air, and photographically reproduced from the original pencil-lines, and being taken at working pressure, with wide-open throttle, unrestricted speed, and full-length stroke, illustrate the action of the machine. At p in the upper diagram the piston is in the position of Fig. 3. At q the exhaust port h is closed and compression begins; at r the port k is opened, full-pressure steam enters, stops the piston at s, and reverses the valve; at t the port i is closed and expansion begins; at u the port h is opened and exhaust takes place. At the lower end of the cylinder there is no gradual rise of pressure like that from q to r. At this end the rise of pressure is practically instantaneous, and the result is the undulations of the lower diagram. While, however, the upper side of the latter diagram is about valueless, the lower side renders clear the action which it is desired to show; as stated, the machine was running at its full stroke—as near to its lower head as was considered safe—nevertheless, there is no lead whatever shown. At v the exhaust from the upper end of the cylinder occurs, and the crossing of the two exhausts produces the flutter shown. The port d is also opened at v, but it is clear that steam is not admitted until the end of a the stroke is reached.

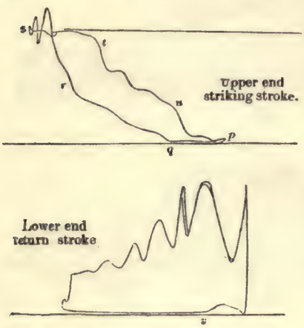


Fig. 7.—Indicator diagram—rock-drill.

It will be observed that the point of cut-off depends upon the position of the ports e i, lengthwise in the cylinder, and can be varied at will in the design and in the two ends of the cylinder independently. The effect of the cut-off on the striking stroke is to diminish the force of the blow, while the effect of the absence of cushion is to increase it. The former may be adjusted to the latter, so that the blow struck is precisely the same as in cushioned-blow machines, but of course obtained with a smaller consumption of steam. On the other hand, a late cut-off may be employed on the striking stroke, thus giving the full effect of the uncushioned blow to increased power. It is freely recognized that fuel is but one of many items of expense, and that in many situations speed of execution far outweighs any economy in fuel that might be realized through the use of the expansion principle. To meet both situations—those where economy and capacity, respectively, are leading objects—two classes of machines are being made, one having cut-off on both strokes and the other on the up-stroke only. The first machine is named the "Economizer" and the second the "Slugger," and either is furnished as the situation requires.

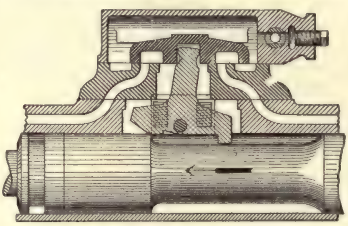


Fig. 8.—Little giant drill.

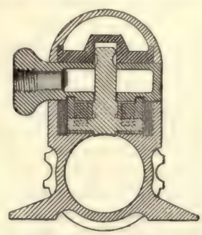


Fig. 9.—Section.

Figs. 8 and 9 illustrate the latest modification of the well-known Little Giant drill. The construction will be manifest from the figures. The object of this change is to obtain renewable bearings for the rocker-pin, and thereby provide for wear.

The Ingersoll "Eclipse" Rock-Drill (Fig. 10 and full page plate).—For a clear understanding of the valve-motion of this drill, refer to the cut on the following page. The principal parts of the machine are the cylinder A, the piston B, the valve and chest C.

The cylinder A is in form a common steam-cylinder, with its live-steam ports P and P', and exhaust-port E. The two dotted circles $F F'$ represent open passages in the cylinder, which are connected with the exhaust port E, and hence the interior of the cylinder between $F F'$ is at all times open to the atmosphere. The two passages $D D'$ are brass tubes opening a passage from the space in the steam-chest at each end of the valves to the interior of the cylinder within the space between F and F'. The piston B, a common engine-piston, moves back and forth in the cylinder, and has a stroke from X to Y. This piston has a long bearing in the cylinder, broken in its center by the annular space $S S'$, making an open space or chamber all around it. The length of the space is such that, wherever the piston may be in the cylinder, this space is at all times open to one of the passages $D D'$, and hence to one of the holes $F F'$, which leads by way of the exhaust port E to the open air. $S S'$ therefore is an exhaust-chamber carried up and down with the piston. When the piston is on the up-stroke it is open to one of these passages, and when on the down-stroke to the other. The valve is spool-shaped, and has a hole through its longitudinal axis, through which passes the bolt T, which serves to guide the valve in its motion back and forth, and which by means of a spline prevents its rolling on its seat. In the bottom of the steam-chest there are two cored passages connecting the tubes D and D' with the ends R' and R of the valve. These passages cross each other, so that R is connected with D' and R' with D. Now refer to the above illustration. The piston has completed the up-stroke; the valve has been reversed, and the drill is ready to strike a blow. We admit the steam through the chest to the valve at a point —say O. As the spaces at O N and N' are in one, the steam will encircle the valve, bearing it down upon its seat through the excess of pressure at O. Escaping over the top of the valve-

Ingersoll Rock-Drill.

flange it will also occupy R'. This being connected with D, and D being closed by the lower piston-head, there is here no outlet. Now, R being connected with D', and as D' is now open to the piston exhaust-chamber, the space behind the valve-flange at R is free to the exhaust; and hence the steam pressure in R' holds the valve close at R so long as D' is open to the

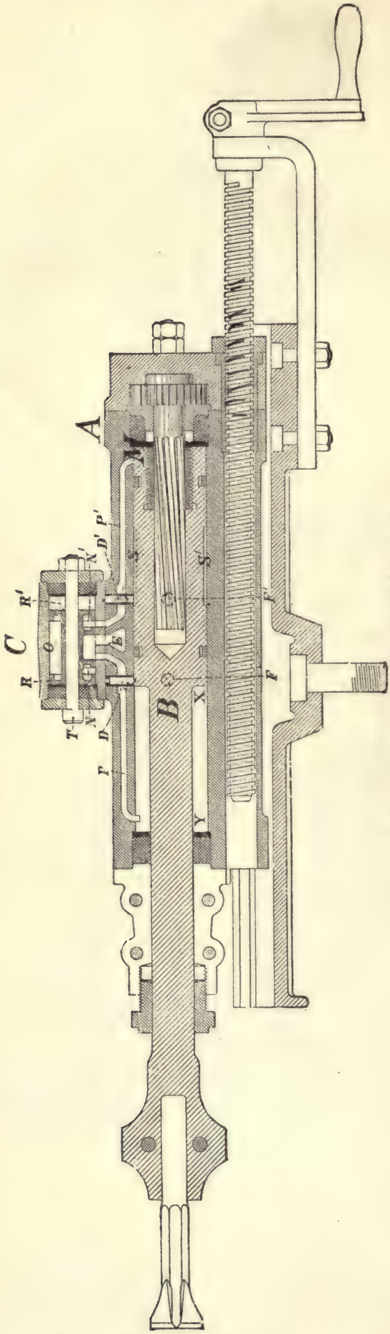


Fig. 10.—Ingersoll "Eclipse" rock-drill.

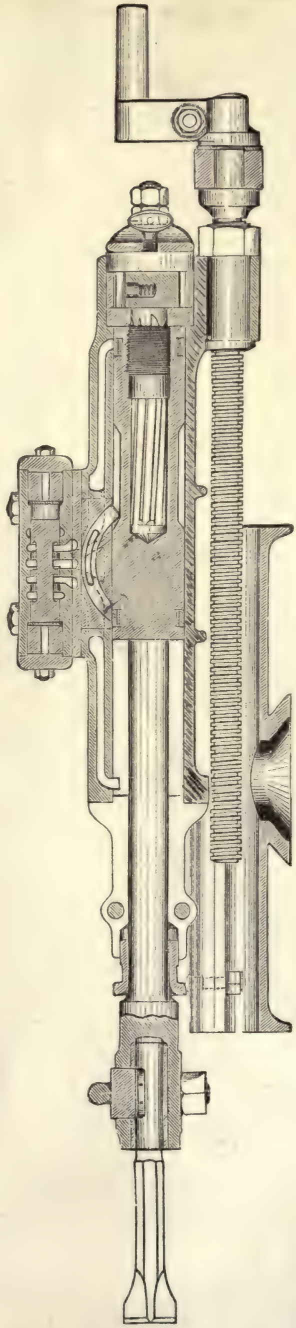


Fig. 11.—Sergeant auxiliary valve-drill.

piston exhaust-passage. Therefore, the valve must remain in its present position until the piston moves. The port P' being open to the live-steam chamber in the valve, and the port P to the exhaust, the steam passes through P' into the cylinder at M, and pressing upon the back of the piston drives it down. As the piston moves down, this piston exhaust-passage

$S S'$ approaches the passage D, and when the distance from D to D' is traversed, the piston exhaust-passage is open to D; and at the same instant D' is shut off by the upper piston-head. The result is that D is suddenly opened to the atmosphere, and the chamber R', being connected with it, is exhausted. The live-steam around the valve rushes toward this exhaust opening, carrying the valve with it, and pressing it against the upper head of the chest at R'; thus the valve is reversed, the machine exhausts, and the motion of the piston is reversed. We here have an intermittent and reciprocative action of piston and valve; one being dependent upon and regulated by the other, yet each is separate and removed from the other, and without direct mechanical connection. The valve motion admits of a variable piston-stroke. By simply feeding down the cylinder the piston will work entirely in the upper part, cutting off so soon as the blow is delivered and increasing its stroke as the hole is driven. This is of value, especially in starting or pointing holes.

The Sergeant Auxiliary Valve-Drill (Fig. 11) is strictly speaking a drill for hard rock. It conbines an independent valve operated through an auxiliary valve, and contains a release rotation. These are the two features distinguishing the Sergeant from other rock-drills. The valve is held in such a position that while the piston carrying the cutting-tool is moved toward the rock the exhaust remains open on one end, while the full pressure acts on the other end until the blow is struck, at which time the valve immediately reverses. The auxiliary is the trigger to the main valve. It opens or closes the steam or air passages, releasing the pressure from one end or the other of the main valve. A new rotating device, with a release movement, prevents twisting of the spiral bar or breaking of pawls and ratchets. When a rock-drill strikes a hard blow upon an uneven surface there is a tendency sometimes to twist the steel in the opposite direction to that in which it rotates. The effect of such a blow on the Sergeant drill is simply to turn the back-head around, overcoming the friction of the back-head springs, when with a rigid rotation it might twist the rifle-bar or break the pawls and ratchets.

The Githens Drill.—In this drill, designed by Mr. George M. Githens, of New York, a positive motion is retained for the valve, while at the same time all moving parts between the piston and the valve are done away with. As shown in Fig. 12, the valve V itself is placed in direct contact with the piston by which it is actuated. Midway, in the length of the piston, is a wide annular recess having a gentle inclined plane at each end. The intervening annular space round the middle of the piston forms the chamber into which the steam or air is first admitted.

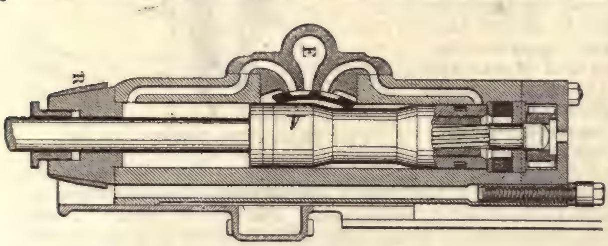
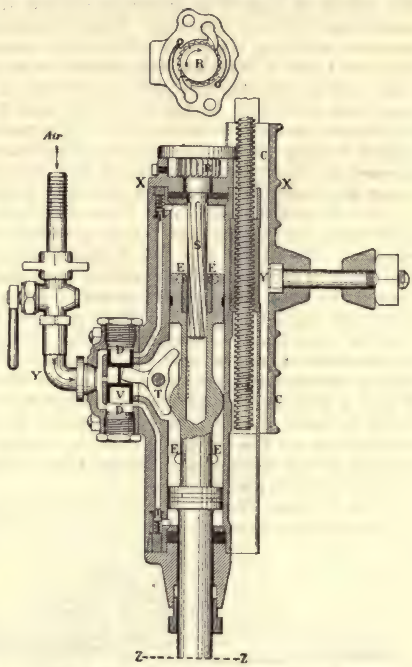


FIG. 12.—Githens drill.

The valve V is over this middle portion, and is in the form of a segment of a circle, fitting accurately against a cylindrical face in the valve-chest, the axis of this face being at right angles to that of the drill-cylinder. In the outer face of the valve is provided a pair of recesses properly proportioned for admitting the air past the valve to the ends of the cylinder alternately. The air being admitted into the middle chamber of the cylinder, presses the valve outward and close up against its cylindrical face; and the piston being at one end of its stroke, the other end of the valve has been raised by the inclined plane, and the valve has been rotated over its curved face, to a sufficient extent to open the port for the admission of the air to the end of the cylinder. The piston is thereby caused to make its stroke, and in so doing it reverses the valve by means of the other inclined plane. At the same time that the admission is taking place to one end of the cylinder, the opposite end is open to the exhaust E through the other recess in the back of the valve. It will thus be seen that the only moving pieces are the piston and the valve.

McCulloch's "Rio Tinto" Drill.—In this drill, shown in Figs. 13 and 14, the two pistons forged solid upon the piston-rod perform the double function of acting themselves as outlet or exhaust valves, and also of actuating the inlet slide-valve V through a tappet T, struck by a swelling or spherical boss surrounding the piston-rod midway between them. The compressed air or steam for working the drill is admitted to the valve-chest, and is distributed by the slide-valve through ordinary ports and passages to the ends of the cylinder alternately. The exhaust takes place direct from the cylinder through two sets of four holes E, which are alternately covered and uncovered by the pistons. The further extremities of the admission-passages, just where they enter the cylinder, are each fitted with a rectangular mushroom-valve I, which opens for admission into the cylinder, but closes against exit therefrom. Hence, after the set of four exhaust-holes in front of either piston has been closed by the piston itself, the exhaust-air remaining in that end of the cylinder is compressed to the end of the stroke, thus forming a cushion, and preventing the piston from striking the cylinder-cover. In the forward-stroke, however, owing to the position of the exhaust-holes, the cushioning does not offer any appreciable resistance to the force of the cutting blow, except when the piston is traveling too far, in consequence either of a soft place in the rock or of the drill not being kept in its proper working position. When the exhaust-air is being compressed in either end of the cylinder, it presses the non-return mushroom-valve I tighter upon its seating; whereas

the corresponding valve at the other end of the cylinder is full open for the admission. the driving air pressure being greatly in excess of the strength of the light spring that tends to close the non-return valve. This action takes place alternately at each end of the cylinder. When the inlet slide-valve *V* has been moved by the tappet to either end of its travel, so as to close one of the admission-ports and open the other, it is retained in that position by the air pressure acting upon its admitting end, and any movement is thereby prevented during the time that the boss on the piston-rod is not in contact with the tappet. The slide-valve is cylindrical, and the cylindrical casing or chest in which it slides is provided with an oil-hole on the outer side, and on the inner side has a longitudinal slot in which the arm of the tappet moves. At each extremity of its travel the slide-valve is pressed by the tappet against a stop, consisting of a steel-disk *D* with India-rubber backing. When desired, both the valve and the tappet can be reversed end for end, for equalizing their wear. During the inward or return stroke of the drill, it is caused to rotate through rather less than a quarter of a turn by means of a rifled spindle *S* fitted into the back-cylinder cover, and carrying a ratchet-wheel *R* with pawls held up by springs, which allows it to rotate in one direction only. On the spindle works a corresponding bush, fitted in the back end of the piston-rod, in which is also made a cavity long enough to receive the spindle when the piston-rod is at the extremity of its inward stroke. When the drill is making its forward or cutting stroke, the ratchet-wheel and rifled spindle are rotated freely by the bush in the piston-rod; while in the return-stroke they are held by the pawls from rotating, and consequently the drill is now rotated by the bush through the extent of the turn provided in the rifling of the spindle. The drill-cylinder is cast with V-shaped projections sliding in corresponding grooves in the cradle *C* in which it is mounted. The feed is given by a screw worked by hand. The cylinder is $3\frac{1}{2}$ in. diameter with a stroke of 5 in.; and the weight of the drill unmounted is 308 lbs.



FIGS. 13, 14.—" Rio Tinto " rock-drill.

Stephens' " Climax " Drill.—In the construction of this drill (shown in Fig. 15), one of the principal features is the reversible tappet-valve *V*, which is a flat plate rocking on a center pin, and actuated by a spherical boss on the piston-rod, midway between the two pistons. The valve contains a pair of admission-ports *A*, and a pair of recesses or exhaust-ports *E*, which control two corresponding pairs of ports in the valve-chest face, communicating with the ends of the cylinder and with the atmosphere. On the back of the valve is another pair of recesses or exhaust-ports, corresponding with those on the face, so that when worn the valve can be reversed back and face and upside down; it is then practically as good as a new valve and new tappet.

A second feature is the twisting or rotating device on the rifled spindle in the back end of the cylinder, which consists of a crown ratchet-clutch *R*, whereby the use of pawls is dispensed with. The strain which would come upon a single pawl and tooth for rotating the drill, or upon a pair, is here distributed equally over 15 catches, which all act at the same time, the sliding half of the clutch being all in one piece, and pressed forward against the rotating half by a single spring. This arrangement admits of the clutch being from 1 in. to $1\frac{1}{2}$ in. larger in diameter than a ratchet-wheel in the same cylinder-cover, because no space is required for pawls and springs outside the circumference of the ratchet. The strain, therefore, besides being distributed over a much larger number of teeth, is also removed to a greater distance from the center. Another feature is the insertion of loose adjusting liners

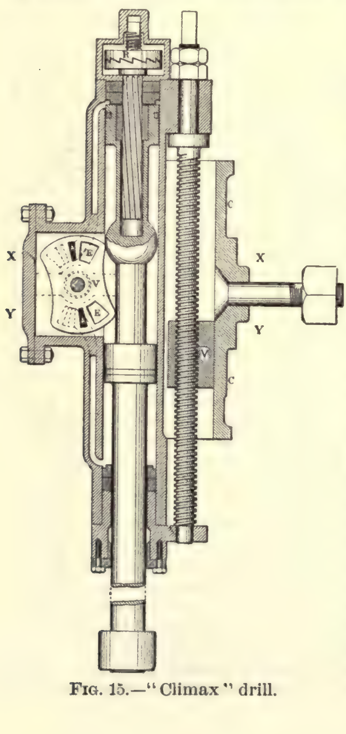


FIG. 15.—" Climax " drill.

L in the cradle C, which are so arranged that any movement of the cylinder in the cradle can be readily adjusted in a few minutes by these loose liners; and provision is made for them in the construction of the cradle. The feed is given by a screw worked by hand. A 3-in. drill unmounted weighs about 240 lb., and a 3½-in. about 280 lb.

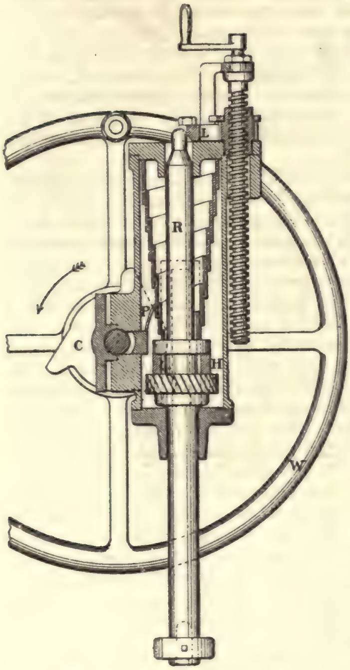


Fig. 16.—Hand-power drill.

Drills driven by Hand-Power.—*Ingersoll Hand-Power Drill* (Fig. 16).—This consists of a strong cast-iron cylinder, shown in Fig. 16, in which works a steel rod R in place of a piston-rod, carrying the drilling-tool at its outer extremity by means of a suitable clip. Across the cylinder at about midway in its length is fixed a shaft, carrying two fly-wheels W, with handles, and two hardened steel cams C, each of which has 3 points, thereby producing 3 blows at each revolution. As the cams revolve they alternately lift and release a steel cross-head H, which is fixed by a collar on the working-rod R, and projects on each side of the cylinder, and is surmounted by a strong volute spring inclosed in the cylinder. The spring is compressed by the lifting of the cross-head, and its recoil on release produces the blow, which is delivered dead on the stone without shock to the men. The spring ordinarily supplied for a drill to be worked by two men is compressed to 200 lbs., and produces with the momentum of the working-rod and drill a blow of about 300 lbs. The rotation of the drill is provided for by a ratchet-wheel with oblique teeth fixed on the working-rod, into which engages a long oblique spring-blade or feather-pawl P, fixed in the thickness of the cylinder, whereby a partial turn is produced in the backward stroke; while in the forward stroke the rod goes free, without any impediment to the blow. The automatic feed is effected by the tail end of the working-rod, which projects through the back cylinder-cover, and is tapered off in a cone at its extremity. As the work progresses, this cone gradually comes within the cover, and permits the inward movement of a small radial lever L, to which is jointed a pawl that works into a ratchet-wheel nut running on the feed-screw. In the backward stroke of the working-rod its thicker part below the cone pushes the lever outward, whereby the pawl is thrust into the ratchet, thus giving it a turn on the screw and feeding the machine forward. This feed adapts itself exactly to the rate of penetration. It can be thrown out of gear when desired. The length of the stroke is 3⅝ in., and the weight of the machine is 300 lbs.

III. Drills driven by Hydraulic Pressure.—*The Brandt Drill* operates through a hydraulic pressure of from 100 to 120 atmospheres, and pierces the hardest rocks after the manner of diamond rock-drills, but with the use of steel tools. The drilling-tool, which is annular in form, is given a rotary motion while being held firmly against the rock. The pressure of the tool against the latter results from the action of water compressed in a cylinder forming a continuation of the tool-carrier. In the interior of this cylinder there is a plunger which abuts against the column that serves as a support to the apparatus. A rotary motion is given the tool by a cog-wheel keyed to the cylinder and actuated by a transverse endless screw set in motion by two small hydrometers placed on either side. The number of revolutions of the drill varies from 5 to 12 per minute, according to the nature of the rock. In the hardest rocks the drilling is effected at the

Fig. 17.

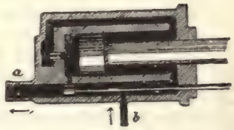


Fig. 18.

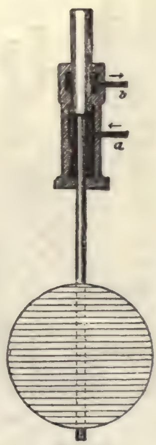


Fig. 19.

Fig. 20.

Figs. 17-20.—Brandt drill—details.

rate of 5 revolutions per minute, and allows of an advance of 4 millimetres per revolution being made. The drilling-machine proper consists of a cylinder and a piston (Fig. 17); the cylinder carrying the drill-rod. By introducing water, under pressure, into the cylinder, the same, and with it the drill-bit, is pressed against the rock. The rotary motion of the drill is imparted by two small hydraulic engines, coupled together under 90°, with differential pistons, and fastened to either side of the cylinder. The valve-motion of these engines is so arranged that the right-hand one steers the left-hand one, and *vice versa*. These engines turn a worm, and by it a worm-wheel, which is connected with the rear end of the cylindrical shell surrounding the pressure-cylinder. This shell carries at its farther end the drill-rod, rotates with the worm, and therefore causes the drill-bit to rotate also. The continuous advance of the drill is effected by the direct hydraulic pressure on the cylinder. The cleaning of the drill-hole is done by the water escaping from the hydraulic engine, and led through the hollow drill-rod to the bottom of the hole.

As further illustrating the principles of the Brandt drill, the following description is given, reference being had to the accompanying engravings:—Fig. 17 is a longitudinal section of the cylinder, with the piston and a cross-section of column. The back part of the cylinder is *uninterruptedly* connected with the pressure-water through the port *a*. Now, if pressure-water is admitted through *b* into the other part of the cylinder and the exit at *c* is closed, the cylinder and with it the drill-rod and bit is pressed forward by a pressure corresponding to difference of the areas of the piston. With *b* shut and *c* open, the cylinder moves backward with a pressure corresponding to the annular area of the piston. With *b* and *c* both closed, the cylinder remains stationary. Fig. 18 explains the principle of the small hydraulic engines, turning the drill. The working-piston is a differential piston. The fore part of the cylinder is continuously connected with the pressure-water through *e*. The distribution of the pressure-water takes place only in the back part of the cylinder by means of a piston-valve. The water used runs off through *a*. Fig. 19 shows the accumulator. The pressure-water is admitted uninterruptedly into the cylinder through the port *a*. If the pumps deliver more water than used, the piston of the accumulator rises above the upper section of the cylinder, allowing the water to escape through *b*. The weight is regulated by the addition of iron plates. The whole machine is supported by a column (Fig. 20). This is constructed after the principle of the hydraulic press, with differential plunger-piston.

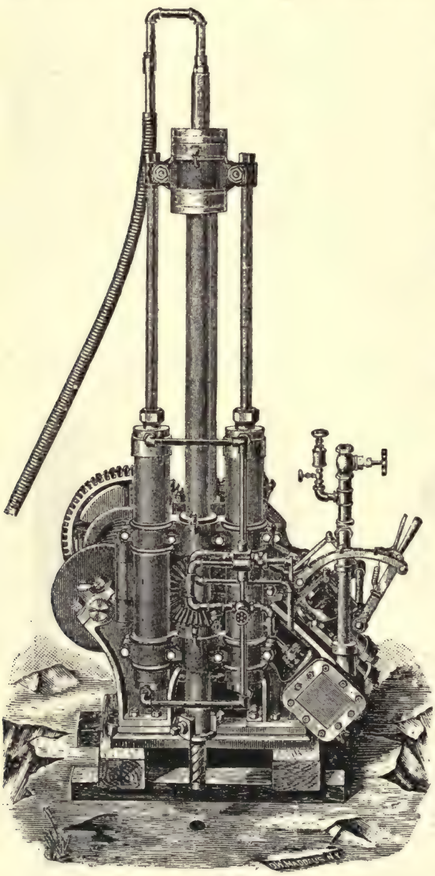


FIG. 21.—Diamond drill.

Diamond Prospecting Drills. — The late improvements in these drills relate chiefly to the feeding mechanism, of which two kinds are now in use, the differential and the hydraulic feed:

1. The differential feed. For this feed the machines have a shaft, 5 to 7 ft. in length, of heavy hydraulic tubing, with a deep screw cut on the outside. The shaft is feathered to the lower sleeve-gear. This is a double gear, connecting by its upper teeth with a beveled driving-gear, and by its lower teeth with the release-gear—a frictional gear at the bottom of the short feed-shaft. At the upper end of the feed-shaft another gear is feathered, connecting with an upper gear on the screw-shaft. This last gear is attached to the feed-nut, in the thread of which runs the screw of the screw-shaft, and as the gear of the feed-shaft has one or more teeth than that of the feed-nut, the nut makes fewer revolutions in a given time than the screw-shaft, thus producing the differential feed. The frictional gear on the bottom of the feed-shaft combines with this a frictional feed, making the drill sensitive to the character of the rock through which it is passing, by maintaining a uniform pressure. The severe and sudden strain upon the cutting points incidental to drilling through soft into hard rock with a positive feed is thus avoided.

The tubular drill-rod passes through the screw-shaft and is held firmly by a chuck, the motion of the screw-shaft being thus communicated to the drill-rods and bit.

In order to run the screw-shaft back after it has been fed forward its full length, it is only necessary to release the chuck and to loosen the nut on the frictional gear, thus allowing the

gear to run loose; then the screw-shaft will run up with the same motion which carried it down, but with a velocity sixty times greater—that is, the speed with which the screw-shaft feeds up is to the speed with which it fed the drill down as sixty to one—the revolving velocity in both cases being the same. The chuck and nut are then tightened, giving the screw-shaft a grip on the drill-rod in a new place, and the drill is ready for another run. The drill-rods may be extended to any desired length by simply adding fresh pieces of tubing, the successive lengths being quickly coupled together by an inside shoulder-nipple coupling, and having a hole bored through the center to admit of the passage of the water. In order to withdraw the drill-rods, they are uncoupled below the chuck; the swivel-head, which is hinged, is unbolted and swung beck—thereby moving the screw-shaft to one side, and affording a clearance for the rods to be raised by the hoisting-gear on the machine, without moving the latter from its place.

2. The hydraulic feed is illustrated in the form of diamond drill shown in Fig. 21. This is an improved method which is substituted for the gear or differential feed, described above. The feed-motion here is accomplished, as its name indicates, by hydraulic pressure, through the medium of two small cylinders and pistons, the piston-rods being connected by a suitable cross-head to the plain hollow spindle, which takes the place of the screw-shaft of the differential feed, and carries the drill-rod. Both ends of the hydraulic cylinders are connected by a system of pipes and hose to the pumps that supply the water necessary in drilling with the diamond bit. The quantity of water admitted to the cylinders is controlled by a four-way cock, which also admits water to either end of the cylinders, as the operator may require. Thus, it will be readily understood, the amount of pressure on the bit is directly under the control of the operator, and only limited by the water-pressure from the supply-pumps; the range being, in ordinary cases, from nothing up to 4,000 lbs. The changes through the whole range of pressure, and also the reversing the motion of the feed, are accomplished by simply moving a small lever while the machine is running at full speed. A pressure-gauge is placed on the pipe leading to the hydraulic cylinders, so that the operator can at all times see just how much pressure there is on the bit. With any constant pressure this feed gives an automatic adjustment of the speed with which the drill is fed forward, the rate of progression depending upon the hardness of the material, being from frequently less than 1 in. per minute in very hard rock to over 2 ft. per minute in a soft substance like coal. The operator, after some experience, can, by comparing the pressure shown by the gauge with the rate of penetration of the drill, tell about what kind of material the bit is boring through, and can make use of the knowledge thus obtained either for speed or for safety. The method of coupling the drill-rods and of withdrawing them is similar to that already described.

IV. Drills actuated by Electricity.—The principle underlying this form of drilling apparatus is fully set forth under Electromotive Engines. Various types of electric drills are in use, but none of them can fairly be said to go beyond the stage of experiment, nor to have given uniformly economical and efficient results.

The Marvin System of Electric Percussion Tools is diagrammatically represented in Fig. 22. Fastened upon a suitable tripod or column is a piece of boiler-tube 7 in. in diameter and about $2\frac{1}{2}$ ft. long. In the forward half of this casing are placed two cylindrical coils of wire in the form of solenoids, each about $8\frac{1}{2}$ in. long, having an outside diameter of about $6\frac{3}{4}$ in., so as to make a loose fit with the casing and an inside diameter of about $2\frac{1}{8}$ in. These two solenoids are placed so as to be against each other and to end in the casing. The bit-plunger plays freely through the center of these solenoids, and is supported by two bearings placed just beyond the outside ends of the two solenoids, respectively. The back portion of the casing contains a spiral spring of the form frequently used for car-springs. The plunger is composed of a central portion made of wrought-iron about 14 in. long, and both the forward and back portion of the plunger, which are made of aluminium-bronze, are rigidly fastened to this iron portion. The forward portion is about 13 in. long and carries the bit-socket. The back portion is spirally milled for a length of about 9 in., so that the cross-section of this portion is hexagonal. At the extreme back end is a steel buffer, which strikes against the cushioning spring.

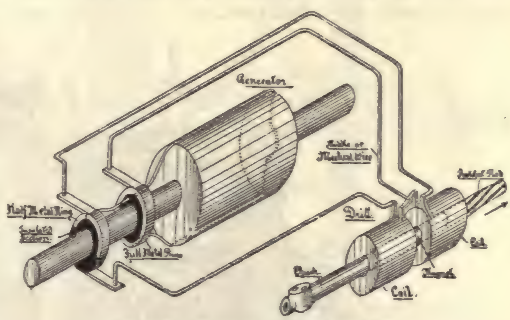


Fig. 22.—Marvin percussion-drill.

The spirally milled portion of the plunger is similar to that used in other percussion-drills, and causes the drill to revolve upon its axis $\frac{1}{6}$ of a complete turn with each stroke. The ends of the coils of wire are brought to contact with pieces at the top of the adjacent ends of the two solenoids, where there is a socket for receiving the terminals of the cable, and thus making electrical connection with the drill. There are three conductors leading from the generator to the drill, one of which is connected with one terminal of each of the solenoids and the other two conductors are connected to the two remaining terminals of the solenoids, respectively. The generator is of the simplest kind, the coils on the armature having their terminals connected with two insulated collars on the shaft. One collar is a continuous metallic ring, and

upon this one rests a brush which is connected with the conductor, which is common to both solenoids. The other collar is metallic for half of the circle, and the remaining half is insulated from the armature wires. Upon this half ring rest two brushes diametrically opposite each other, and each brush is connected with one of the two remaining conductors leading to the solenoids in the drill. If we now revolve the armature of our generator in a separately excited magnetic field, an electric current will flow. Let us say, from the armature to the half ring, then through one of the two brushes which happens at the instant to be in contact with the half ring along the corresponding conductor to one terminal of one solenoid, let us suppose the rear one. Then through the rear solenoid itself and back along the mutual wire to the continuous ring, and then to the armature again. This current in passing through the rear solenoid makes a powerful magnet of it, and this tends to pull the plunger back into a position such that the center of its iron portion shall be in the center of the rear solenoid.

When the armature moves forward a half revolution the polarity of its wires is reversed, and the other brush with its conductor is now in contact with the half circle. Consequently, the current in the mutual wire will be in the reverse direction from that of the former wave; the rear solenoid and its conductor, formerly active, are now out of circuit, and the circuit is made through the other conductor and its corresponding solenoid—that is, the forward solenoid. The magnetic action of this solenoid now tends to make the plunger move forward, so that the center of the iron portion shall be in the center of the forward solenoid. Thus we get a reciprocating action of the plunger, and every revolution of the armature of the generator will cause a complete stroke of the drill. By varying the speed of revolution of the generator we can make the drill strike any number of blows per minute we choose. In usual practice 600 blows per minute are found to give good results. An exterior view of a rock-drill of this type is given in Fig. 23. The drills are operated in parallel; three wires lead from the two drill-coils to the generator, comprising two distinct circuits, each circuit including similar coils in the drills. Over these two circuits electrical impulses are sent in alternation. One impulse moves the iron bar or plunger back, and the next moves it forward; thus the drills all move together and in synchronism with the generator. The drill makes about 600 strokes per minute, and the stroke of the plunger is from 3 to 4½ in. The heaviest single parts of the drill are the tripod-weights, which are about 100 lbs. each. Next to these in order of weight are the two coils, which weigh about 60 lbs. each. The largest piece in the entire drill is the cylindrical casing, which is 38 in. long by about 7 in. in diameter.

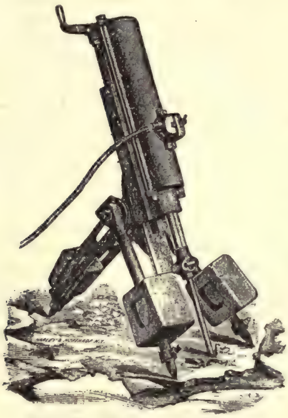


FIG. 23.—Electric rock-drill.

The Van Depoele Electric Percussion Rock-Drill consists of two or more coils of copper wire inclosed in an iron tube, and a wrought-iron core moving within them. To one end of

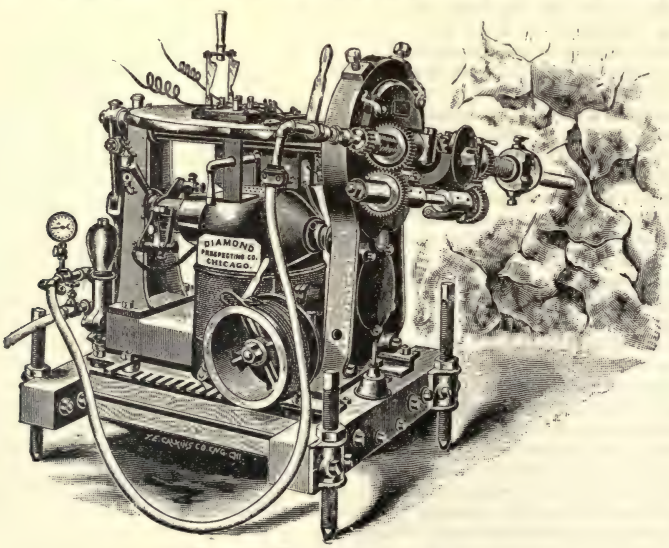


FIG. 24.—Electric diamond-drill.

the core is fastened a rifle-bar rotating the drill, to the other a rod carrying the drill-chuck. The action of the drill depends upon the following experimental fact: An iron bar placed

within a coil of copper wire through which a current of electricity is flowing will, if free to move, take up a central position in the coil or solenoid. If two coils are placed side by side, and the current allowed to flow first through one coil, then through the other, a reciprocating motion will be imparted to the bar. The drill makes about 400 strokes per min., and the length of the stroke is from 4 to 5 in. Both speed and length of stroke may be varied to suit the character of the rock by adjustment of the dynamo. The short stroke necessary on starting the bit is obtained by feeding the drill close up to the face of the rock.

The Electric Diamond-Drill (Fig. 24) is a representation of a class of electric drills differing widely from those above described. The drill is rotated by suitable gearing communicating with a rotary electro-motor. A current of sufficient capacity to deliver 3 horse-power at the drill-motor is required. The motor is mounted on the same frame as the drill, together with the pump and hoisting-drum with wire rope. The claimed capacity of this machine is a hole 300 ft. deep, $1\frac{1}{2}$ in. in diameter; the core produced being $\frac{15}{16}$ in. in diameter.

FIG. 25.—Lifting-jack.

Fig. 25 represents an *Improved Lifting-Jack for Use in Diamond-Core Drilling*, which is operated as follows: The two levers to which the rings of chain are attached are cam-shaped. By pressing down on them the jaws are forced apart by a pair of springs, and pass over the end of the drill-rod. The operator then starts his hoisting-machine, bringing a strain on the two pieces of chain, drawing ends of levers together, and throwing the cam-faces against the jaws, which come in contact with the drill-rod, gripping it firmly. The jaws have teeth or serrated faces, which prevent their slipping on the rods, and the action of the double cams is such that, the greater the strain upon the ring above, the tighter they close upon the rods. When the rod is hoisted to the required height, the safety-clamp is tightened below, and the strain on the rope is withdrawn; the ends of the levers, thus being allowed to drop back to a horizontal position, release the jaws from the rod. The lifting-jack is slipped off from the end of this rod and lowered to take hold of the next length of rod.

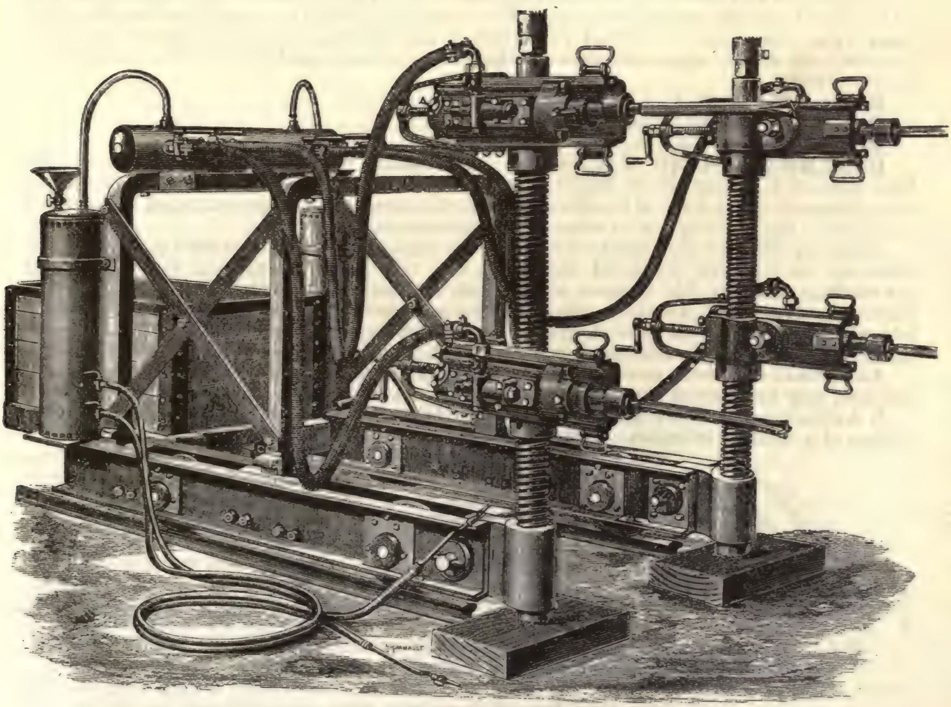


FIG. 26.—Drill carriage.

Fig. 26 represents a new carriage support, designed by Mr. Richard Schram to carry four of his drilling-machines. The carriage carries two stretcher-bars, each of which supports two drilling-machines, the arrangement of the carriage and bars being such that trucks for the removal of *débris*, etc., can be run right through it, so that it is unnecessary to provide any sidings in which to run the carriage when the removal of spoil becomes necessary. This arrangement has the further advantage that the drilling machinery can be brought up to the

working face before all the *débris* has been removed. In cases where timbering is necessary, and the stretcher-bars have to be lowered to clean up, arrangement is made whereby these, with their machines, can be turned back down on to the carriage. The small receiver shown on top of the carriage is for the distribution of air, and it has two inlets and four outlets, corresponding to the number of drills. The tanks shown on each side are the water-injectors, the injection being effected by admitting air under pressure above the surface of the water.

Rock-drills are mounted in various ways for different classes of work. The full-page plate of Niagara Tunnel (see Niagara, Utilization of) illustrates the Rand drill adapted to

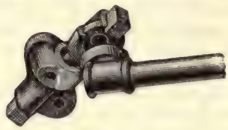


FIG. 28.

FIG. 27.

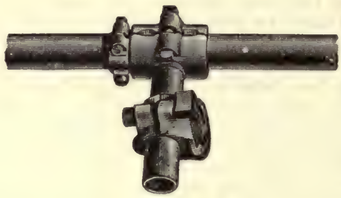


FIG. 29.

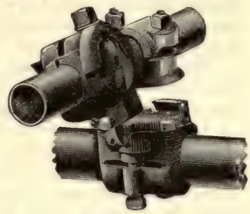


FIG. 30.

FIGS. 27–30.—Rand drill—detail of mountings.

various classes of work. Figs. 27 to 30 illustrate various features of these mountings, the chief requirement in all cases being universal adjustability. Fig. 27 illustrates the universal joint of the Rand machine as mounted upon its tripod; Fig. 28 the universal joint by which the front leg of this tripod is attached to the rest of the structure; Fig. 29 illustrates the corresponding universally adjustable parts of the tunnel column; and Fig. 30 the same parts of the shaft-bar.

Dryer, Ore: see Mills, Silver.

Duster: see Milling Machinery, Grain.

Dynamite Gun: see Gun, Pneumatic.

DYNAMO-ELECTRIC MACHINES. The various types of modern machines differ from those of ten years ago in details of construction and improvements brought about by a more thorough recognition of the theory of such machines, and the application of well-defined methods for their calculation in advance of construction.

PARTS OF DYNAMO-MACHINES.—The principal organs of all dynamos are the *armature* in which the currents are generated, and which, as a rule, forms the moving or driven part of the machine; and the *field magnets*, which create the magnetic field through which the armature-conductors pass. To these principal organs we may add the *commutator*, or *collector*, into which the currents generated in the armature are led, and the *brushes* which bear upon the commutator, and are connected with the external circuit.

ARMATURES.—Various constructors have adopted different forms of armatures, which, however, may be grouped under four general heads, as follows:

1. *Cylindrical or Drum-Armatures*, in which the coils are wound longitudinally over the surface of a drum or cylinder. This type of armature is shown diagrammatically in Fig. 1, which illustrates a 4-part drum-armature with closed coil. In practice, of course, the coils thus wound may reach several hundreds in number, with a corresponding number of commutator-bars. Armatures of this type are employed in the machines of Edison, Weston, Siemens (Alteneck), Stanley (alternating), and a large number of others. A modified form of the drum-armature is employed in the Thomson-Houston arc-light dynamo (see below) which has a spherical shape.

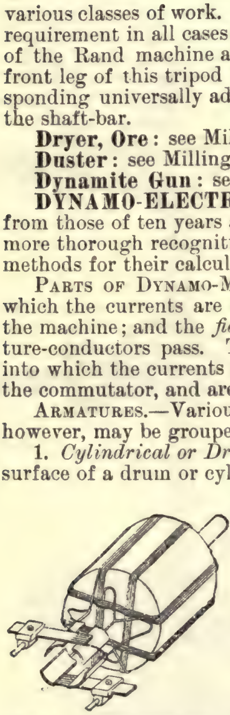


FIG. 1.—Drum-armature.

Drum-armatures, a typical form of which (Weston) is shown in Figs. 54 and 55, are usually built up of disks of the softest charcoal-iron, insulated from each other by layers of tissue-paper, and screwed together to form a solid cylinder, which is keyed to the shaft. The core thus formed is covered with canvas soaked in shellac, and upon it the insulated wires are wound. The object of building up the core with thin disks is to avoid the formation of Foucault or "eddy" currents, which absorb power, and which would quickly heat the armature and destroy the insulation of the wires. In the early types of these armatures teeth were generally employed on the periphery, but were later on abandoned; practice, however, at present tends strongly to their re-employment, as they serve to decrease the resistance of the magnetic circuit and to aid largely in holding the wires firmly in place.

2. *Ring-Armatures.*—In these the coils are wound around an iron ring, usually mounted

on a spider of brass or gun metal keyed to the shaft. This type is shown diagrammatically in Fig. 2. This illustrates the usual type of Gramme armature, and, as will be seen, the coils form one continuous winding, which is tapped at the proper intervals, and connected by short wires to the commutator-segments, against which the brushes bear. Ring-armatures have been adopted by a large number of constructors, among them Pacinotti (who was the first to use a ring-armature with teeth), Gramme, Brush, Schuckert, Fein, etc. This type of armature is coming more and more into general use, on account of its simple construction; repairs are made easy, owing to the independence of each coil, which can be removed without interfering with the others.

FIG. 2.—Ring-armature.

Various methods have been employed in the construction of the iron core in ring-armatures. In order to avoid the generation of Foucault currents, Gramme employed a ring built up of iron wire covered with a Japan compound, so as to insulate the convolutions from each other. Later constructors have used hoop or band iron wound as a continuous spiral, the layers of which are insulated by paper. The most recent machines of approved type have cores built up of ring-shaped soft iron disks, insulated from each other, and pressed together to form a hollow cylinder. The wires are, as a rule, wound on the surface of the core, but in some recent machines, such as those of Brown and Wenström, the wires are led through holes close to the periphery of the armature, being thus entirely imbedded in the iron. This avoids the use of the band wires usually employed to hold the wires in place, and allows the iron of the armature to be brought close to that of the pole-pieces, thus reducing the magnetic resistance.

3. *Pole-Armatures.*—In this type the generating coils are wound on iron cores projecting radially from the axis. This type has been employed by Lontin, Gramme, and others, and by Weston in his electroplating machines. It is now practically obsolete for large direct-current machines, owing to the difficulty of constructing it sufficiently strong, as the cores require to be laminated. Besides this, the number of poles which can be employed is limited, and when closely crowded they react injuriously upon each other.

Disk-Armatures.—These may be divided into two classes: (*a*) Those in which a number of independent coils wound on bobbins, either with or without iron cores, are placed side by side in a circle, and revolve under the influence of a number of poles of successively opposite polarity. This type is specially adapted for the generation of alternating currents, and has been successfully employed by Wilde, Holmes, Siemens—who used iron cores for the coils—and in the more modern machines of Mordey and Ferranti (see below), in which iron cores are discarded. (*b*) Those in which the cores overlap a considerable angle of the periphery, as shown in Fig. 78 (see below), which represents the arrangement adopted in the Desroziers machine. Similar arrangements have been adopted by Edison, Pacinotti, Ayrton and Perry, Jehl and Rupp, and more recently by Fritsche, the latter machine being known as the "wheel dynamo," on account of its peculiar shape. (For practical examples of machines employing these various types of armatures see below.) In general, care must be taken to reduce the length of an armature conductor as much as possible, in order to reduce the internal resistance of the machine, to overcome which involves the consumption of power. In some machines the low resistance of the armature is the very basis of its regulating properties, as, for instance, in the shunt-machine (see below). Theoretically the form of armature requiring the smallest length of wire for a given surface of magnetic induction is the circle. This has been carried out in the Thomson-Houston machine (old type), and is also followed in the cores of some armatures of the ring type. But the advantages gained are not commensurate with the difficulties encountered in construction, and the rectangular form of section is now generally adopted. Only the best quality of copper with the lowest resistance should be employed, for reasons similar to those stated above.

The number of armature sections or coils to be employed varies considerably with different conductors; their number should, however, never be so small as to cause an appreciable fluctuation in the strength of the current. Armatures should be designed so as to avoid excessive heating in the conductors; on account of the constant ventilation to which they are subjected they are capable of carrying a far heavier current than conductors placed in moldings, and without access to the circulating air. Thus, while in the latter case a current of 1,000 ampères per sq. in. of copper would be a safe limit, in a well-ventilated armature a current density of 2,500 ampères per sq. in. is permissible. According to Ayrton and Perry, the permissible continuous output of a machine is a maximum when the thickness of the winding on the armature is such that the magnetic resistance of the air-space occupied by the winding on the armature is equal to the resistance of the rest of the magnetic circuit. Modern practice points to the following proportions in ring-armatures: The thickness of external armature winding is from 7 to 11 per cent of the diameter of the iron core, and in drum-armatures from 9 to 13 per cent. (For actual windings, etc., adopted, see description of machines below.)

Open and Closed Coil-Armatures.—According to the nature of their winding and their connection with the commutator, armatures are divided into *open* and *closed coil* types. In the open coil type, of which the Brush dynamo is an example, the opposite coils are connected together and joined to two commutator segments, and form an independent circuit, there being an *open circuit* between them and the remaining coils. In the *closed circuit* type (see Fig. 2) such as the Gramme and Siemens drum-type, each coil, besides being connected to the commutator-strips is connected directly to its neighbor, and forms one continuous winding, the coils forming a closed circuit. The former construction allows of the cutting out of circuit of those armature-coils which are not doing useful work when out of the influence of the mag-

netic field. This serves to reduce the internal resistance of the machine, and to increase its efficiency somewhat. Open-coil machines are used almost exclusively for constructions in which it is desired to secure high potentials rather than heavy currents, as in arc-light machines.

Armature Windings.—In the ring, disk, and pole type of armature the winding or windings are practically continuous and symmetrical, but in the drum-armature there is much scope for devising combinations, in order to secure, first, an equal length of wire in each coil; and, second, the shortest length of wire capable of giving the required E. M. F. Figs. 3, 4, 5,

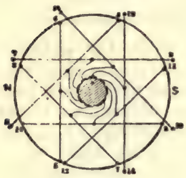


Fig. 3.

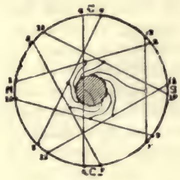


Fig. 4.

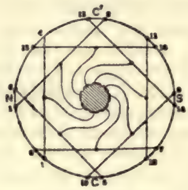


Fig. 5.

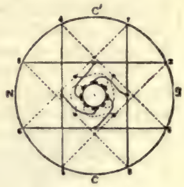


Fig. 6.

Figs. 3–6.—Armature windings.

6, and 7 show various methods of armature-winding employed by different constructors. The early armatures of Hefner-Alteneck (Fig. 4) were wound unsymmetrically, on account of the simple construction, and better insulation of which it permitted. Subsequently Froelich invented a symmetrical winding (Fig. 3). Breguet has designed a large number of windings, among them, Figs. 5 and 6, and showed that with eight commutator segments eight different symmetrical windings were possible; that winding should, of course, be selected which, with the same inductive capacity, will have the shortest length of wire. Breguet calculates that for the ends of the drums the following lengths of wire are necessary for the various systems: Froelich winding, 30·8; Hefner-Alteneck winding, 30·5; Breguet winding, 26; Breguet (another) winding, 28·4; Fig. 7 shows one style of winding of the Edison armature which is

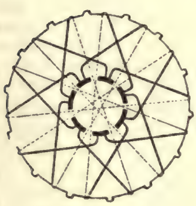


Fig. 7.

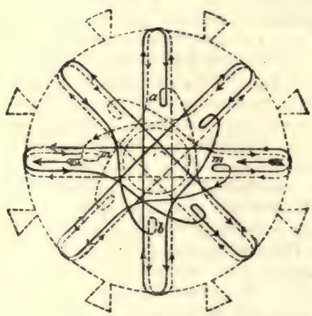


Fig. 8.

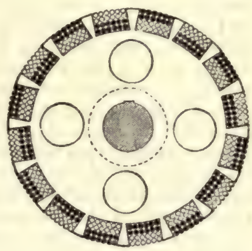


Fig. 9.

Figs. 7–9.—Armature windings.

symmetrical, but which has an uneven number of divisions. Fig. 8 shows a diagram of one type of the Weston winding, and Fig. 9 a section through the armature; it will be noted that the layers of wire successively change from outer to inner, thus equalizing the potential generated in each.

There are also various methods of winding closed coil ring armatures. The simplest, of course, is to wind as many sections as there are collector-rings, and connect the junction of contiguous coils to each bar. Another method is to wind twice as many sections as there are bars in the collector, each section being united either in series or parallel with that diametrically opposite it, and the pair so united being treated as a single section in the coupling up of the ring.

When ring-armatures are employed in multipolar fields, a variety of methods of connection are possible. That of Mordey is shown in Fig. 10. It consists in adding to the usual Gramme winding a system of cross-connections between those portions of the armature-circuit which arrive simultaneously at equal potentials. This may be done by cross-connecting either the bars of the collector or the wires of the winding. In 4-pole machines each bar must communicate with that situated 180° from it; in 6-pole machines, with those situated at 120° from it. Mordey's method, as applied to a 4-pole machine, is shown in Fig. 10, which shows connections of a simple 8-part ring. It will be noted that only two brushes, and these at 90° apart, are required to collect the currents.

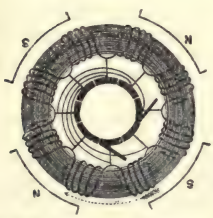


Fig. 10.—Mordey armature.

Another method suggested by Prof. Perry, in 1882, is applicable only to armatures wound with an odd number of sections. The diagram in Fig. 11 relates to an 11-part armature in a 4-pole machine. In this method the successive sections of the coil are not connected together, as in Gramme's winding, but each coil

is connected across to that coil which lies nearest the diametrically opposite point, or, if there are c sections, each section is connected to the sections $(\frac{1}{2}c - 1)$ beyond. The coils still form a closed circuit, but the total electromotive force from brush to brush is the sum of the electromotive forces in half the coils, while in Mordey's method it is but one quarter. Mordey's method has the contrary advantage of reducing the resistance to one quarter, and is preferable for low potential machines.

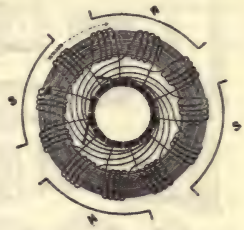


Fig. 11.—Perry armature.

Field Magnets.—While the employment of permanent magnets, as in the older types of machines, would involve no expenditure of energy in order to obtain the required magnetic field, they are now practically discarded, as the field which can be produced by them is weak, compared with that which can be produced by electro-magnets. In all modern machines, therefore, the latter are employed. In the construction of magnets for dynamos, iron alone can be employed, on account of its high magnetic susceptibility. Present practice is now tending largely to the employment of wrought iron, on account of the greater magnetic power developed in it for a given current. The softer the iron the greater its magnetic susceptibility, the ratio of cast iron to wrought iron being, approximately, as 2 to 3; that is, a given magnetizing force will create 50 per cent more lines of force in wrought than in cast iron. In designing field-magnets care should be taken to make them of ample size, so that they may not become too quickly saturated; and it is desirable to have the magnet as thick as possible, so that it may react slowly to changes in the main circuit, and thus steady the current induced in its field. Magnets should. theoretically, be so constructed that they may receive the highest magnetizing effect with the shortest possible winding; this is the case when the magnet is circular in shape. Some constructors, however, employ rectangular slabs of wrought iron, as they are cheaper than circular cores of equal cross-section. In the design of field-magnets, care should be taken to avoid all sharp corners, as the magnetism strays or escapes from such points into the air and is wasted. The laws of distribution of magnetism follow closely those of static electricity.

The Magnetic Circuit.—As in the construction of the armature it is desirable to reduce the length of the conductors as much as possible and thus the electric resistance; in a similar manner it is advisable to reduce the length of the magnetic circuit. The magnetic circuit in a dynamo is made up of two principal components, namely, the iron and the air-gap. The modern theory of construction of the dynamo is based largely on the recognition of this important fact: As the magnetic resistance of the air is over 700 times greater than that of soft iron, it is of the highest importance to bring the iron of the field-magnets as close as possible to that of the armature-core. Constructors are evidently limited in this direction by the clearance necessary between the revolving armature covered with conductors and the pole-pieces. To reduce this clearance, some constructors place the conductors of the armature below the periphery of the armature, so that the latter can be run to within $\frac{1}{32}$ in. of the pole piece. Another general method of reducing the magnetic resistance is by the employment of pole-pieces. The latter, frequently made of cast iron, encircle a greater or less portion of the armature, and afford a proper path for the passage of the lines of force. In all cases the grain of the wrought iron employed should lie in the direction of the path of the lines of force, passing through it, and joints in the magnetic circuit should as far as possible be avoided.

Forms of Field-Magnets.—The design of field-magnets permits of great variations, and the machines of different constructors are characterized principally by the type or shape of field-magnet adopted in their machines. The principles of construction above enumerated may be taken as a general guide. While it has been pointed out that, theoretically, it is better to employ one magnetic circuit instead of two or more, modern constructors are largely employing multipolar machines both for continuous and alternating current work, the object being to reduce the speed of the machines, especially those of higher powers. Again, in many cases the double circuit or consequent pole type of field-magnet is preferable from a mechanical standpoint.

The accompanying engravings (Figs. 12, 13, and 14) show the principal forms of magnets employed at the present time (*Thompson*). No. 1 in these illustrations shows the form adopted by Wilde for use with the shuttle-wound armature of Siemens. Two slabs of iron are connected at the top by a yoke, and are bolted below to two massive pole-pieces. There are four joints in the magnetic circuit, in addition to the armature-gaps, and the yoke is insufficient. No. 2 shows the form adopted in the latest Edison dynamos (American pattern). The upright cores are stout cylinders. The yoke is of immense thickness, the pole-pieces are massive, but their useless corners are cut away. There are as many joints as in Wilde's form, but such a circuit would possess a far higher magnetic connectivity than Wilde's, owing to the greater cross-section. One difficulty with such single circuit forms is, how to mount them upon a suitable bed-plate. If mounted on a bed-plate of iron, a considerable fraction of the magnetism will be short-circuited away from the armature; hence, an intermediate bed-plate of zinc some inches deep is interposed. In the larger form (No. 10) used by Edison in his "steam dynamos" (old type) this difficulty is partially obviated by turning the magnets on one side. The favorite type of field-magnet, having a double magnetic circuit with closed poles, is represented in No. 3; it was introduced by Gramme. It may be looked upon as the combination of two such forms as No. 1, with common pole-pieces. Nos. 3 to 9 may be looked upon as modifications of a single fundamental idea. No. 4 gives the form used in the Brush dyna-

mo, the two magnetic circuits being separated by the ring-armature. The diagram will serve equally for many forms of flat-ring machine; but in most of these the poles at the two flanks of the ring are joined by a common hollow pole-piece, embracing a portion of the periphery of the ring. No. 5 shows the well-known form of Siemens, with arched ribs of wrought iron, having consequent poles at the arch. The circuit is here of insufficient cross-section. No. 6 depicts the form adopted by Weston; and very similar forms have been used by Crompton, and by Paterson and Cooper. There is a better cross-section here. No. 7 is a form used by Bürgin and Crompton, and differs but slightly from the last. It has one advantage, that the number of joints in the circuit is reduced. No. 8 is a form used by Crompton, Kapp, and by Paterson and Cooper. No. 9 is the form adopted in the little Griscom motor. No. 18 is a further modification due to Kapp. No. 19, which also has consequent poles, is used by McTighe, by Joel, and by Hopkinson ("Manchester" dynamo) (see below), by Clark, Muirhead & Co. ("Westminster" dynamo), by O. E. Brown (Oerlikon) (see below), by Blakey, Emmott & Co., and in some of Sprague's motors, but with slight differences in proportions of the details. The main difference between No. 19 and No. 6 lies in the position selected for placing the coils, No. 19 requiring two, No. 6 four. No. 20, which is the design of Elwell and Parker, is a further modification of No. 3. In No. 3 (Gramme) it is usual to cast the pole-pieces and end-plates, but to use wrought iron for the longitudinal cores. The requisite polar surface must be got by some means, and, when the core was made thin, the two courses open were either to fasten upon the core a massive pole-piece (Nos. 1, 3, 4, 6, 7, 19, 20), or else to arch the core No. 5 so that its lateral surface was available as a pole. Now, however, that it is known that massive cores are an advantage, the requisite polar surface can be obtained without adding any polar expansion or "piece," but by merely shaping the core to the requisite form (No. 8). This must not be regarded as a mere thinning of the magnet; for, though mere reduction of cross-section at any part of the circuit would reduce the magnetic conductivity, reduction of the thickness for the purpose of bringing the armature more closely into the circuit will have quite the opposite effect. Nos. 11 to 15 illustrate forms of field-magnet having *salient* as distinguished from *consequent* poles. No. 11 is the double Gramme machine designed by Deprez. Nos. 12 and 13 are two of the innumerable patterns due to Gramme himself. These are both of cast iron; and it will be noticed that in No. 13 there are no joints, it being cast in one piece. No. 14 is the form used by Hochhausen, and is practically identical with 21, save in the position of the axis of rotation. The iron flanks of No. 14, however, tend to produce a certain short-circuiting of the magnetism by their proximity to the poles. No. 15, used by Van Depoele, is similar. No. 16 is the form used by Sylvanus Thompson in small motors, and is cast in one piece. The semicircular form adopted for the core was intended to reduce the magnetic circuit to a minimum length. No. 17 illustrates the form used by Jürgensen, having salient poles re-enforced by other electro-magnets within the armature. No. 21 shows in section the double tubular magnets of the Thomson-Houston dynamo, the spherical armature being placed, as in Nos. 12, 14, and 15, between two salient poles. There is a curious analogy between Nos. 21 and 19; but they differ entirely in the position of the coils. No. 22 is a design by Kapp, in which there are two salient poles of similar polarity, and two consequent poles between them, one pair of coils sufficing to magnetize the whole quadruple circuit. Almost identical forms have been employed by Kennedy ("iron-clad" dynamo), and by Lahmeyer and by Wenström. No. 23 (Fig. 13) is a type which, used long ago by Sawyer and by Lontin, has recently become a favorite one, having been revived almost simultaneously by Gramme ("type supérieur"), by Kapp, by Siemens ("F" type), by Cabella ("Technomasio"), and lately by Paterson and Cooper. No. 24 is Brown's very massive form. No. 25 is a design by Kennedy, known as the "iron-clad" dynamo; the iron cores are forged

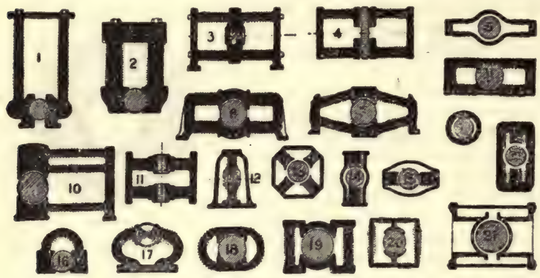


Fig. 12.—Field-magnets.

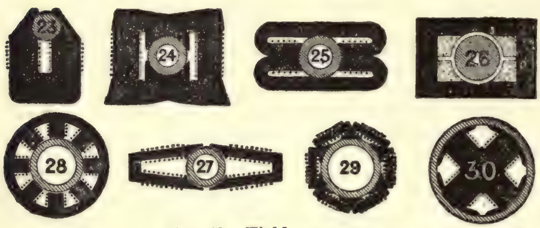


Fig. 13.—Field-magnets.

Fig. 14.—Field-magnets.

to shape. No. 26 is designed by Prof. George Forbes. The iron-work is in two halves; the coils, which are entirely inclosed, are so placed as to magnetize the armature directly, one coil occupying all the available space between the field-magnet and the upper half of the armature, the other the similar space around the other half. No. 27 is the 4-pole form adopted by Elwell and Parker in some of their larger machines. No. 28 is a multipolar form used by Wilde, Gramme, and others, the poles which surround the ring being alternately of opposite sign. In No. 29, a modification of this design by Thury, for use with a drum-armature, the six inwardly directed poles are magnetized by coils wound upon the external hexagonal frame. No. 30 is a sketch of the latest form adopted by Siemens and Halske, wherein an external ring rotates outside a very compact and substantial 4-pole electro-magnet (see below). A similar 6-pole machine has been designed by Ganz, of Buda-Pesth, and a 4-pole also by Fein. Another recent form of field-magnet is shown in No. 31. This, which is a single horseshoe with but one coil upon it, was designed by S. P. Thompson early in 1886; and a similar form was independently designed by Messrs. Goolden and Trotter about the same time. One-coil machines have also been recently designed by Schorch, of Darmstadt, and by R. Kennedy, of Glasgow, by Immisch, and by J. G. Statter & Co. No. 32 represents also a machine requiring but one coil, and is of the iron-clad type. It was devised by McTighe in 1882, and has been recently revived by Messrs. Stafford and Eaves. No. 33 represents the latest machine of Messrs. Fein, of Stuttgart, with inward-pointing poles.

The amount of magnetic leakage that takes place in the various forms of field-magnet differs greatly in different forms. No doubt there is least waste field in those machines which have the most compact magnetic circuits, fewest joints, and fewest protruding edges and corners. The magnetic lines of the waste field sometimes takes curious forms, which have been experimentally explored, in various types of machines, by Mr. Carl Hering. (See Hering's *Principles of Dynamo-Electric Machines.*)

It was stated above that, theoretically, the best cross-section for field-magnet cores was circular, as this gave the greatest area for least periphery, and therefore presumably would for a given lengh of wire in the coil give the largest amount of iron to be magnetized. This, of course, means that if the length of wire and the number of turns be given, a core of this section will, of all possible shapes of core, take the greatest number of ampères to bring it to the diacritical point of semi-saturation. Prof. S. P. Thompson discovered, in 1884, that either the electromotive force or the current of every dynamo is proportional to that number of ampère-turns which will bring its core to this diacritical point. This discovery, according to Thompson, renders it more than ever needful in designing dynamos to adhere as closely as possible to the rule to make the core of circular section whenever the construction will admit of it. Again, as was pointed out by Hopkinson, it is a mistake to construct a field-magnet with two or more parallel cores uniting at a common pole-piece; for not only is the wire between the two cores useless, it is worse, because it offers wasteful resistance. To divide the iron that might be in one solid cylindrical core into two parallel cylindrical cores implies, of course, that for every turn of wire two turns must be used, each of which is more than half as long as the original one, the total length being increased as $\sqrt{2}:1$, while the magnetizing power is actually reduced. The following calculations of Thompson are added, which show the area (in square centimetres) inclosed in a number of different forms of section, the total periphery of each one being one metre:

Circle	796
Square	625
Rectangle, 2 : 1	555
Rectangle, 3 : 1	469
Rectangle, 4 : 1	400
Rectangle, 10 : 1	236
Oblong, made of square between two semicircles	675
Oblong, made of two squares between two semicircles	548
Two circles (section of two parallel cores, as in Edison "L" and Siemens "F 34" machines)	398
Three circles (section of three parallel cores, as in Edison "K" and early Weston dynamo)	265
Four circles (section of four parallel cores, as in Gramme vertical dynamo)	199
Eight circles (section of eight parallel cores, as in Edison "Jumbo" steam-dynamo)	99

Commutator or Collector.—These are usually built up of segments of copper or phosphor-bronze, insulated from each other as well as from the shaft. The insulation now generally preferred to separate the segments is mica, though in some recent machines of Siemens the collector-bars, made of iron, are separated by air-spaces. The air-space was adopted by a number of constructors in the early stages of electric lighting, among them Weston and Hochhausen, but was discarded on account of the liability to the settling of dust and the bridging of copper particles across the air-space, resulting in the short-circuiting of the armature. Connection between commutator and armature wires should in all cases be soldered, as screws are apt to work loose. The commutator requires constant care, and should not be allowed to wear into grooves or ruts, which eventually give rise to destructive sparking. For lubrication, oil is avoided if possible, as it is apt to settle among the bars, harden, and carbonize, and finally short-circuit the bars. For that reason French chalk is frequently employed;

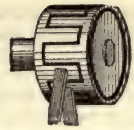


FIG. 15.—Commutator.

but more recently the application of carbon brushes has overcome many difficulties connected with the commutator. Another class of commutator, sometimes employed for self-exciting, alternate-current machines, is shown in Fig. 15.

Brushes.—These are employed to take the current from the commutator-bars and deliver it to the working-circuit. Various forms are employed, among them those shown in Fig. 16. The object in all cases is to secure as good a contact as possible between commutator and brush, and hence the latter has been given the forms shown. In *A* a number of copper wires are grouped into a brush soldered together at their ends. In *B* a flat strip is slit longitudinally, while in *C* a series of strips are soldered together and bear edgewise on the commutator. Within the past few years "carbon brushes," as they are called, have come into extensive use, especially in connection with motors. They are made up of a pressed mass containing coke and a certain percentage of plumbago, which gives them excellent lubricating qualities. Their great merit, however, lies in the fact that they do not burn perceptibly, and hence have a long life, at the same time protecting the commutator from wear. Brushes made of copper wire-gauze are also largely in use.

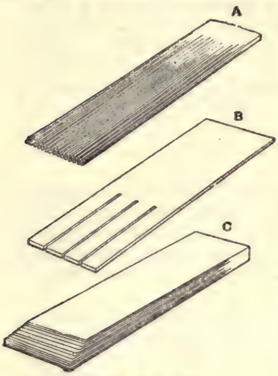


FIG. 16.—Brushes.

Method of connecting Armature and Dynamo.—Excitation.—Governing.—The methods of the connection of the armature to the field-magnet, as well as the mode of excitation of the dynamo-machine, are most intimately connected with its regulating properties. Magnetism may be excited in the field-magnets in various ways.

1. *Magneto-Dynamo.*—This type, shown in Fig. 17, is the oldest employed, and has permanent steel magnets. This form is still used in small machines for special purposes, as in magneto-calls, telephones, etc., and for experimental work, but has long been discarded in large machines on account of the great weight of the machine for a given output, and also because the permanent magnets gradually diminish in strength, and thus reduce the output of the machine. On account of their simplicity, however, permanent magnets are still employed in machines of the De Meritens type, intended for light-house work. (See *Alliance*, *Pixii*, and other magneto-machines, pp. 519, 520, old edition.)

2. *Separately Excited Dynamo.*—This type was employed by Faraday and later by Wilde in 1866 (see p. 522, old edition). This machine, as well as the magneto-dynamo, has the field-

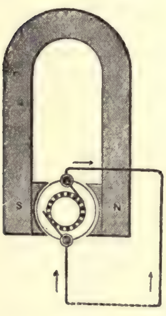


FIG. 17.

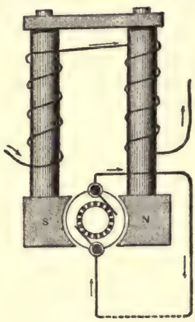


FIG. 18.

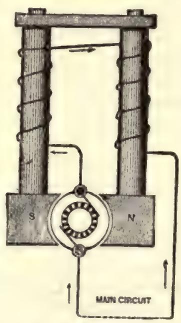


FIG. 19.

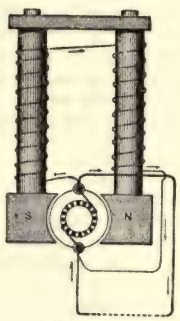


FIG. 20.

FIGS. 17-20.—Types of dynamos.

magnetism constant, and hence the E. M. F. generated is independent of changes in the external circuit. Both the preceding types of machines may be regulated either by altering the speed or by varying the magnetism passing through the armature. Fig. 18 shows the method of connection.

3. *Series-Dynamo.*—This is the type of machine now generally employed for arc-lighting, and which is specially adapted to furnish currents of constant strength. As shown in Fig. 19, the armature, the external circuit, and the field-magnet windings, are all connected in series, so that the current is of equal strength in all parts of the circuit. This type of machine does not begin to generate current until it has attained a certain "critical" speed, as below this speed the magnets do not become excited; this speed depends upon the resistance of the circuit. This type of machine is also liable to have its polarity reversed; hence, it is not employed in electro-plating or charging storage-batteries.

4. *Shunt-Dynamo.*—This type is the one most generally employed at the present time for constant potential machines, such as are used for incandescent-lighting. The connections are shown in Fig. 20. The armature here feeds two independent circuits: (*a*) the main circuit, which connects with the lamps, and is indicated by the heavy line and arrow; (*b*) the shunt circuit, which energizes the field-magnets. The shunt circuit consists of fine wire, usually

measuring several hundred times the resistance of the armature, and is so arranged that it takes only a small fraction of the total current of the machine (usually not exceeding from 3 to 5 per cent). According to theory, a machine of this type, having no resistance in the armature and an infinite resistance in the shunt circuit, ought to be self-regulating—that is, when kept at constant speed, the potential, or E. M. F., remains constant, no matter what the load on the external circuit. In practice these conditions are, of course, impossible to carry out. But machines are now frequently built in which the ratio of armature resistance to shunt resistance is so great that the regulation is practically perfect.

5. *Separate-Circuit, Self-Exciting Dynamo.*—Another type of self-exciting machine is one so arranged that a set of coils, either wound on the same core as the main armature or constituting a separate armature, but rotating in the same field, feed the exciting field-magnets. This method has been applied for exciting alternate-current machines, and more recently by Thomson and Lahmeyer for motor-dynamo distribution. It has also been proposed by Edison for low-tension electric railways, with the rails as conductors.

6. *Combination Methods of Field Excitation.*—Besides the above simple methods of field excitation, a variety of plans have been invented for securing absolute regulation without external means. These methods consist in various combinations of the series—shunt, separate, and magneto methods. Among these is the series and shunt, or "compound" dynamo. In this method, patented by Brush in this country, and shown in Fig. 21, the field-magnets have both a series and a shunt winding. The action produced by this combination is to keep the field-magnets of constant strength at all external loads. In the plain shunt-machine the current in the shunt diminishes as the current in the external circuit increases, or, to put it in another way, as the resistance of the external circuit decreases. By adding the series winding, the current passing around the field-magnets is increased to the same amount as that in the shunt decreases; hence, the magnetism remains constant. There are two ways of connecting the shunt to the series-circuit, the one just described and the series and long shunt. The latter has, however, not been put into practice. The compound-machine is in extensive use for incandescent-lighting, especially on shipboard, and is specially adapted for maintaining constant potential. Various combinations have also been designed to obtain constant current automatically, among them the shunt and separate, invented by Deprez; the shunt and magneto, invented by Perry; and the shunt and series, by S. P. Thompson. Although theoretically possible, the methods of compounding for constant current are not as a rule carried out in practice, the methods of regulation employed being applied by external regulators, the principal ones being described below.

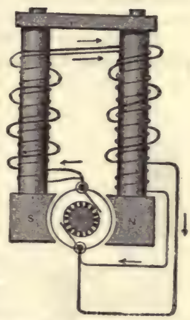


Fig. 21.—Compound dynamo.

7. *Other Methods of Regulation.*—The method of regulation most generally employed in series (arc-light, constant-current) machines consists in shifting the brushes so as to reduce or increase the potential in proportion to the resistance of the internal circuit. At the position of maximum load the brushes make contact at or very close to the "neutral point," but as the load decreases the brushes are shifted away so that they approach nearer and nearer a position of right angles to the first position. This method of regulation is carried out in the Thomson-Houston, Wood, Hochhausen, Maxim, and Western Electric Co.'s, and a number of other arc-machines. (For details of operation, see the description of these machines given below.)

The automatic regulator of Brush employs a variable shunt resistance connected to the terminals of the field-magnet (Fig. 22), the resistance of the shunt being controlled by an electro-magnet placed in the main circuit. The dynamo at D pours its current into the circuit, leaving the commutator by the upper brush, whence it flows through the field-magnets $F\,M$, and round the circuit of lamps $L\,L$, back to the negative terminals. Suppose, now, some of the lamps to be extinguished by switches which short-circuit them; the resistance of the circuit being thus diminished, there will be at once a tendency for the current to increase above its normal value, unless the electromotive force of the dynamo is at once correspond-

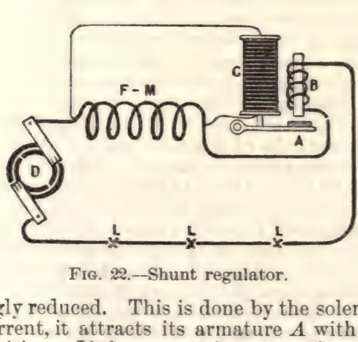


Fig. 22.—Shunt regulator.

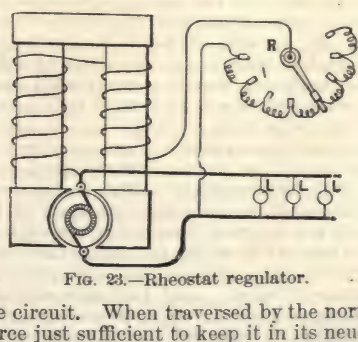


Fig. 23.—Rheostat regulator.

ingly reduced. This is done by the solenoid B in the circuit. When traversed by the normal current, it attracts its armature A with a certain force just sufficient to keep it in its neutral position. If the current increases, the armature is drawn upward, and causes a lever to compress a column of retort carbon-plates C, which is connected as a shunt to the field-magnet.

These plates when pressed together conduct well, but when the pressure is diminished their imperfect contact partially interrupts the shunt circuit and increases its resistance. When *A* rises and compresses *C*, the current is diverted to a greater or less extent from the field-magnets, which are thus under control.

For regulating the potential of constant potential (incandescent-light) shunt-machines, Edison first employed a variable resistance placed in series with the field-magnet coils. The arrangement is shown in Fig. 23. As the potential increases, resistances are thrown by moving the handle of the rheostat *R*, which diminishes the current in the field-magnet coils, and hence their magnetic power, and thus reduces the potential of the machine to its normal value. On a decrease of potential, due to increased load, the rheostat resistance is reduced, which reverses the action just stated. The operation of the rheostat has also been carried out automatically in various ways. Besides the methods just enumerated, others have been employed. In Lane-Fox's regulator, a high-resistance relay is connected as a shunt to the mains, and actuates the rheostat as described above. Regulation can also be effected by winding the field-magnets in sections, and cutting these sections in, or out, in proportion to the load. This method has been employed by Deprez, Brush, Hochhausen, Van Depoele, and others. Still another method consists in placing a magnetic shunt across the field-magnets, and thus diverting the lines of force from the armature as the load decreases. This has been carried out by Goolden and Trotter in their constant-current machine (see below).

Regulation can also be effected by governing the steam-engine, so that its speed is exactly proportional to the load. In Richardson's electric governor (Fig. 24) the valve which admits steam to the engine is a double-beat equilibrium valve *E*; its stalk passes upward and is acted upon by a plunger *R*, which is pressed down by the shorter arm of a lever *L*, which is in turn connected with a long vertical spindle having a weight *C* at its lower end, and at its upper end carrying the iron core *B*, surrounded by the solenoid *A*. A spring *S* counterpoises the slight upward pressure of the steam on the valve. When the current passes through the solenoid *A* it lifts the core *B* to a certain height, and admits to the engine a sufficient quantity of steam to drive the engine at the speed requisite to maintain the current. Should the resistance of the circuit be increased by the introduction of additional lamps, the core *B* will fall a little, thereby turning on more steam, until the speed has risen to that now necessary. For additional safety a separate electro-magnet *a* is added, which, when in action, holds up the heavy iron block *b*. Should the circuit from any cause be broken, the block *b* instantly descends and cuts off the steam. Similar engine-governors have been devised by Willans, Jamieson, and others. Further information respecting electric governors, and their actual applications in various installations of electric-lights, may be found in the following papers: A. Jamieson, Electric-Lighting for Steamships, *Proc. Inst. Civ. Engrs.*, vol. lxxix, session 1884–'85, Part I: F. W. Willans, The Electric Regulation of the Speed of Steam-Engines, *Proc. Inst. Civ. Engrs.*, vol. lxxxi, session 1884–'85, Part III. (See also *Thompson's Dynamo-Electric Machinery.*) Dynamo-metric governing has also been proposed, the regulation being effected by the action due to the variation in torque with varying load. Governing by steam-pressure has also been proposed. In this system the steam-pressure is kept constant, and equal quantities of steam admitted in each stroke between the speed. The principles above enumerated have been carried out in a large number of designs of machines, each having its special peculiarities and advantages. For the sake of obtaining a better understanding of the various types, we have in the following grouped dynamo-electric generators primarily into two divisions: continuous-current and alternate-current dynamos.

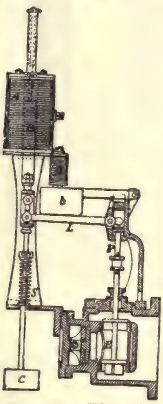


Fig. 24.—Electric governor.

1. Continuous-Current Dynamos.—These may be divided into (*a*) *constant current* and (*b*) *constant potential* machines; the former were those first brought to practical perfection, and hence we shall take them in that order, giving examples of the machines in most general use, together with the regulating methods employed for keeping the current constant.

The Brush Arc-Light Machine.—The most characteristic feature of the Brush machine (see p. 527, old edition) lies in the form and construction of its armature, which consists of a built-up iron ring, the cross-section of which is generally rectangular, but in the direction of its circumference it is alternately wide and narrow, as shown in Fig. 25, which represents the iron armature-ring and explains its construction. On reference to this figure it will be seen that the ring is divided up into as many sectors as there are bobbins to be wound by a number of rectangular depressions or grooves; in these the coils of insulated copper wire are wound until the groove is filled up, and the flat, converging recesses become flush with the face of the intermediate thicker portions or pole-pieces, by which they are separated from one another. All the coils are, like those in the Gramme machine, wound in the same direction. Fig. 26 is a diagram illustrative, not only of the distribution of the coils around the ring, but of the method by which the connections are made; the inner ends of each of the coils is connected by a wire to the inner end of the corresponding coil, at the opposite end of the same diameter of the ring, and the outer ends of all the coils are brought through the shaft of the machine, and are connected to corresponding portions of the commutator, where the currents are collected by suitably placed copper plates. Referring to the diagram, it will be seen that the inner end A^1 of the coil 1 is connected to A^5, which is the inner end of the coil 5; A^2 is connected to A^6, A^3 to A^7, and so on round the ring, and the outer ends, B^1 B^2 B^3, etc., are

all connnected to the commutator by conducting wires insulated from one another. The two free ends of each pair of diametrically opposed coils are, after passing through the shaft of the machine, attached respectively to two diametrically opposite segments of the same commutator, which segments are insulated from one another and from any other pairs of coils. The commutator which is attached to and rotates with the driving-shaft of the machine consists of a set of separate copper rings or flat cylinders, of which there are as many on the shaft as there are pairs of coils on the armature, and each of these cylinders consists of two segments insulated from one another on one side of the shaft by a small air-space about $\frac{1}{8}$ in. wide, and on the other by a piece of copper separated from the segments by two smaller air-spaces. The arrangement is shown in Fig. 27, in which A and B are the two segments connected, respectively, to corresponding coils on opposite sides of the armature, and attached by an insulating material to the shaft S; C is the copper insulating piece, the object of which is to separate either of the flat copper brushes or collectors, which press upon the periphery of the commutator, from either of the segments during the interval occupied by one pair of coils passing the vertical, or, in other words, through the neutral portion of the magnetic field; this occurs twice in each revolution of the armature, and therefore of the commutator. At the time when any pair of bobbins is in this way cut out of the general circuit, their own circuit is open, so that no current can circulate or be induced in them. By this arrangement each pair of coils has in succession, in each revolution, a period of rest equal to one quarter of a revolution, and has a current passing through it for only 75 per cent. of the time the machine is running; to it is in a great measure due the very small development of heat in the working of the Brush machine; and it presents also another important element of efficiency to the machine, namely, that each pair of bobbins as it passes the neutral portion of the magnetic field, and is therefore incapable of doing work and contributing electro-motive force to the general current, is itself cut out of the circuit.

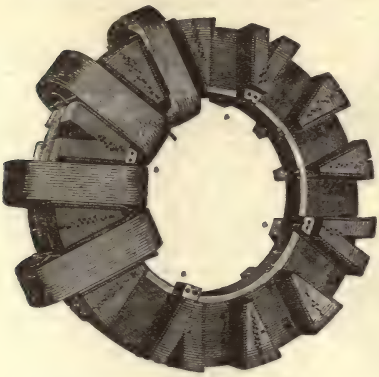


Fig. 25.

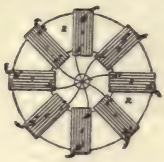


Fig. 26.

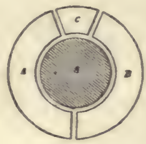


Fig. 27.

Figs. 25-27.—Armature—Brush dynamo.

Fig. 28 is a diagram illustrating the connection between the armature-bobbins and the magnet-coils at the time when the commutators are placing them in the same circuit. Referring to this diagram, $M\,M$ and $M\,M$ are the two magnets having their similar poles presented toward one another on opposite sides of the armature-coils $A\,A^1$. Thus, the coil A is under the influence of a magnetic field produced by the two north poles $N\,N^1$, while at the same time its corresponding bobbin A^1 is under the influence of the two south poles $S\,S^1$. A current is therefore induced in the pair of bobbins $A\,A^1$ which is transmitted by wires passing through the shaft S to the commutators $C^1\,C^2$, whence it is collected by the brushes B^1 and B^2, and by them transmitted to the magnet-coils, which are all connected together in series, and at the same time the other portions of the commutators (which are in connection with the other armature-bobbins) are in contact with the brushes B^3 and B^4, by which they are placed in the external circuit of the machine.

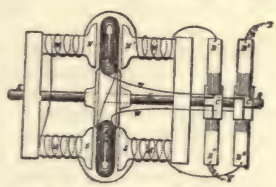


Fig. 28.—Brush dynamo.

One of the most original features of the Brush machine is the commutating apparatus, which collects and distributes the currents from the active armature-coils, and cutting out of circuit the armature-coils one by one as they pass through the neutral regions between the poles. The commutating apparatus consists of two pairs of rings attached to and revolving on the main shaft, and therefore their position is fixed with respect to the revolving armature of the machine. On to the cylindrical circumferences of these rings are placed two pairs of copper-collecting brushes, which run tangentially against the commutator rings, one pair pressing above, and the other pressing below, a line forming the points of contact being a diameter of the ring. The copper brushes are flat strips of elastic copper about 2 in. wide, cut at the ends which press against the rings into 8 tongues, so as somewhat to resemble a grainer's comb, and each comb or brush is wide enough to cover or be in contact with two armature-rings; and in this way, although two of the coils are insulated twice in each revolution, the main circuit is never interrupted. The disposition of the brushes with respect to the commutators will clearly be understood by comparing Fig. 28.

The Thomson-Houston Arc-Light Machine.—This machine, probably the most extensively employed arc-dynamo at the present time, is the joint invention of Profs. Elihu Thomson and E. J. Houston, although many of the details embodied in the recent machines are due to Prof. Thomson solely. The general appearance of the complete machine is shown in Fig. 29.

The field-magnets consist of two large hollow castings. The large flanged portions of the castings are united magnetically by a series of bars of soft iron, and are firmly held in place by bolting to the side-frame, which also affords feet for the machine and sustains the shaft in its bearings.

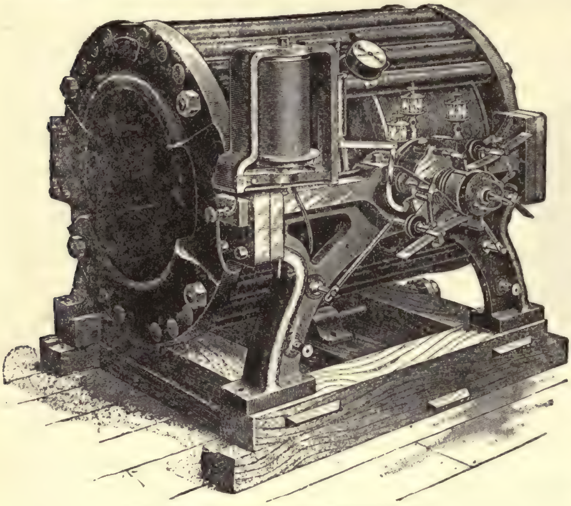
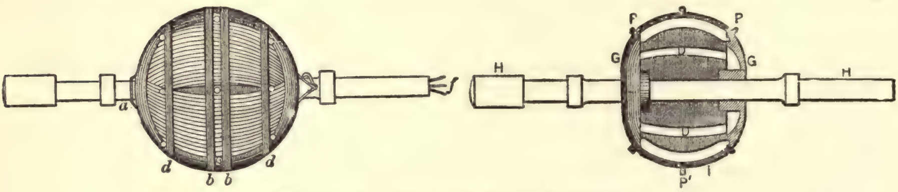


Fig. 29.—Thomson-Houston dynamo.

The armature, spherical in form (Fig. 30) is nearly inclosed. The commutator and air-blast mechanism, therefore, occupy positions upon that portion of the shaft outside the bearing. The wires, three in number, from the armature helices are brought out through the hollow shaft and connected to the commutator at the end of the shaft. The armature-core consists of an iron shell, having the form of an oblate spheroid, mounted centrally upon the shaft, as seen in Fig. 31, the shaft *H H* passing through the axis of the spheroid. The polar portions are formed of two thin iron castings, placed, as shown, at *G G*, and keyed firmly to the shaft. Between these flanges, and supported by them, but insulated therefrom, are a series of cast-iron bridges *D*, generally 12 in number, and placed at equal distances apart. The bridges are formed with feet that enter corresponding grooves in the internal faces of the flanges. Outside the bridges is wound a quantity of well-annealed soft-iron wire *I*, scaled by heat and shellacked. The depth of the wire varies with



Figs. 30, 31.—Thomson Houston armature.

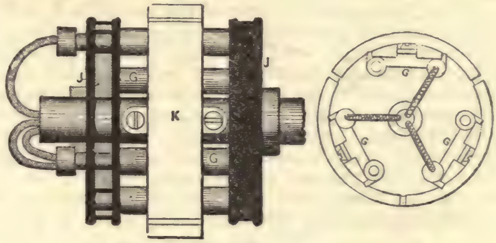
the capacity of the machine, and, when all on, completes the form of the spheroidal armature. The core is covered with several layers of insulating paper, and then is wound with insulated copper wire. To facilitate this winding, hard-wood pins *P P* are carried by being inserted into openings in the flanges near their periphery. The core so formed is wound with three helices crossing one another at the polar portions, and being divided centrally by the shaft in its passage through the core. To secure mechanical and electrical equality of the three coils or helices, the following procedure is adopted: The first half of the first coil is wound; the first half of the second coil is next wound; the whole of the third coil is then wound; the second half of the second coil is then wound; finally, the second half of the first coil finishes the winding, and produces an approximately spherical outline, as shown in Fig. 30. The coils are thoroughly insulated, and are interwoven with tapes, wherever necessary to keep them in place. Finally, a strong brass-wire binding is applied, consisting of two central bands *b b* and two lateral bands *d d*, wound around the armatures circumferentially.

The three ends from the inner ends of the coils are joined together permanently at *a*, while the three outer ends *f* are carried through the shaft to the commutator. By this winding the highest differences of electric potential are found only upon the outside wires, the result being greatly in favor of retention of insulation under all conditions. The position of the coils upon the armature is such that they follow each other in similar electrical sequence at 120° of a revolution apart, an arrangement which gives, with the small number of generating helices, an approximate continuity of effect. The three free ends are carried out through the shaft, and kept well insulated while passing to their connections at the commutator near the end of the shaft.

The commutator consists of a copper ring, slit into three segments of 120° nearly. These segments are independently mounted upon a metal frame, which gives the segment its position. The three metal frames *G G G* (Figs. 32 and 33), for the support of the segments, are mounted in two metal flanges *J J*, but thoroughly insulated from them. The flanges *J J* are themselves borne upon the shaft and covered with a layer of vulcanite. The segments are readily detachable by removal of screws passing through lateral ears extending from each

side of a segment, K. The wires from the shaft connect to each framework $G\ G\ G$ respectively, and consequently there is one wire electrically connected to each segment.

Fig. 34 shows diagrammatically the winding of the armature and also the manner of applying the brushes to conduct the current to the circuit. There are usually two pairs of brushes, formed of comb-like copper springs, the brushes of each pair being diametrically opposite, and the two brushes that are positive or negative set so as to bear upon the commutator at points about 60° apart, as shown. The figure also shows at $C\ C$ the relation of the field-coils to the rest of the circuit $L\ L\ L$.



Figs. 32, 33.—Dynamo-frame.

The commutator-brushes are, however, made movable, those diametrically opposite being mounted upon yokes in insulated holders, so as to be capable of movement around the commutator-shaft. The purpose of this arrangement is to permit the automatic setting of the brushes to maintain a standard current, irrespective of changes of speed and of resistance in the circuit.

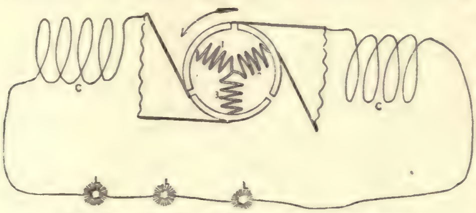


Fig. 34.—Thomson-Houston commutator.

The brush-holder yokes are connected to a lever and connecting rods L, Fig. 35, so that the brushes $R\ R$ receive a movement backward $3\frac{1}{2}$ times as great as that imparted to $S\ S$ forward during regulation. This movement is effected by an attachment to the connecting arm A from the motor magnet lever N, Fig. 36. The motor-regulator magnet is constructed of a stout U-shaped iron frame, to the center of which is bolted a bar of iron, surrounded by a magnetizing coil, K, of low resistance. The polar extremity of this bar, P, is a projection having an approximately paraboloidal form, and its armature, A, is provided with a circular opening, the edges of which are rounded so as to move over the pole without contact. The armature is swung upon pivots at U, between the legs of the U-frame. The construction is such that the ends of the armature move at equal distances relatively from the frame at each end, leaving the pivots U without strain. A dash-pot, D, is provided, to prevent too sudden movements. The attraction exerted by such a magnet, when a constant current flows through its coils, is practically constant in all positions of the armature within its prescribed range. It is seldom, however, sufficiently sensitive to current fluctuations to serve alone as a means of regulation. It is therefore put under the control of a shunting contact, operated by what is termed a current-controller magnet. The controller-magnet (Fig. 37) is constructed of two helices $C\ C$, placed side by side and serving as solenoids attracting into their interior a double-core B, the parts of which are yoked together and suspended by an adjustable spring, S, from the support above. The yoke carries a contact-point on its under side, and a stationary contact-point, O, is mounted immediately thereunder. When these contact-points are touching each other they complete a shunt-circuit of practically no resistance around the coil K of the regulator-motor magnet (Fig. 36). To avoid sparks at the contacts, a permanent shunt of carbon coils, inclosed in glass tubes, is connected around the contacts. The connections are exhibited in Fig. 38, where K is the commutator, $C\ C$ the mag-

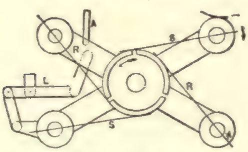
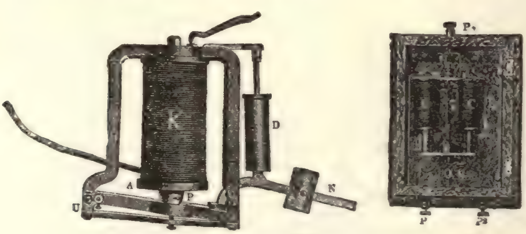


Fig. 35.—Brush-holder.



Figs. 36, 37.—Regu'ator-motor magnet.

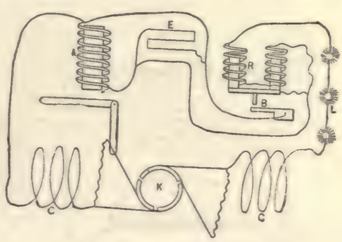


Fig. 38.—Connections.

net-coils, A the motor-regulator, R the controller, B the contact-points, E the carbon resistance. Every slight fluctuation of the line-current is felt by the controller-magnet, and the result is that when set for normal current a tremor of the contact-surfaces is constantly taking place, so that the magnet A (Fig. 38) is maintained at such a state of excitation as will cause it to move and maintain the brushes at those positions corresponding to a predetermined current under variations of speed and of resistance, even down to a short circuit. The regu-

lation is effected so promptly that a machine may have all its lights shunted at once without damage. Unsteady power does not practically injure the steadiness and uniformity of the lights or current.

One of the novel features of the machine is the air-blast attachment to the commutator. It was invented for the purpose of permitting the use of electromotive forces up to 2,000 volts and over, while a free oiling of the commutator-surfaces is still permissible for diminishing wear, a single commutator being used, and that containing but three segments. It is based upon the discovery by Prof. Thomson that a strong jet of air of small amount can effectually break any conducting line of particles tending to bridge the commutator-slots, and cause the local discharge termed "flashing." Small nozzles are mounted directly opposite the tips of the foremost positive and negative commutator-brush. At the moment the slot in the commutator passes the tips of the brush, a puff of air is sent through the slot and repeated at every slot. These small puffs are furnished at the proper instant by a small rotary, positive-blast mechanism (Fig. 39), which is mounted upon the journal-box at the commutator side of the machine, and within which are carried by a slotted hub *H* (rotated by the shaft *S*) a set of three hard-rubber wings loosely placed in the slots in the hub at *R R R*, 120° apart. An inclosing case of interior elliptical outline is divided by the hub *H* into two lune or crescent-shaped chambers, into which the rubber wings are thrown by centrifugal force during rotation. Inlet openings are provided at *I I*, covered with fine wire gauze to exclude particles. The outlets are at *J J*, and communicate with the nozzles over the commutator-slots. By this construction, when the parts are correctly set, six puffs of air are obtained at every rotation, three from each nozzle, alternating in succession from the nozzles, and corresponding to the times of passage of the commutator divisions or slots past the ends of the forward brushes. The advantages obtained by the use of the air-blast for high electromotive-force currents are great. It removes all that sensitiveness to oil which is generally present in such cases. The Thomson-Houston machine can be run with a steady stream of oil pouring upon the commutator, and, there being no carbonizable material collecting at the commutator segments, no fear of short circuits of armature-coils need be apprehended from that cause.

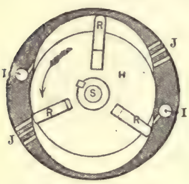


FIG. 39.—Air-blast.

When used as a generator, the armature-coils successively traverse the opposed field-spaces, and the impulses so produced in them find connection through the commutator-brushes to the circuit. The armature-helices act for a portion of the time in multiple arc of two coils, as when they are traversing field-spaces where the impulse is considerably below the maximum, and act alone or in series with the other coils, when they are producing their maximum impulse. These actions necessarily result from the three-coil or three-branched armature system. The mode of application of the brushes is such that when the electromotive force of one branch or coil has fallen below that of the branch or coil which follows it in sequence during rotation, the current is transferred to the latter, and the former coil, although it has not yet reached neutrality, is instantly put by the commutator into connection with the opposite commutator-brushes, there to act in supplanting that branch which is about to leave said brushes. This mode of carrying off the currents will be understood by reference to Fig. 34. It possesses the apparent anomalous condition of putting a commutator segment, just before the coil or branch to which it is attached has reached neutrality of electrical action, into momentary contact or electrical connection with both positive and negative brushes of the machine. This condition, however, gives rise to no perceptible inconvenience, and this latter fact is accounted for by the powerful effect of the field-magnet helices in preserving the volume and direction of the current at the instant of the connection just referred to.

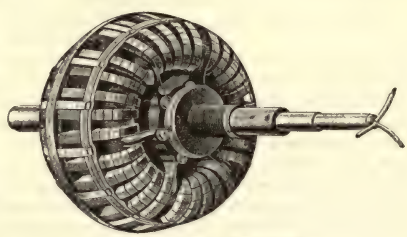


FIG. 40.—Ring-armature.

During regulation the positions of the brushes are so altered as to enlarge this period of connection, and so diminish the available electromotive force

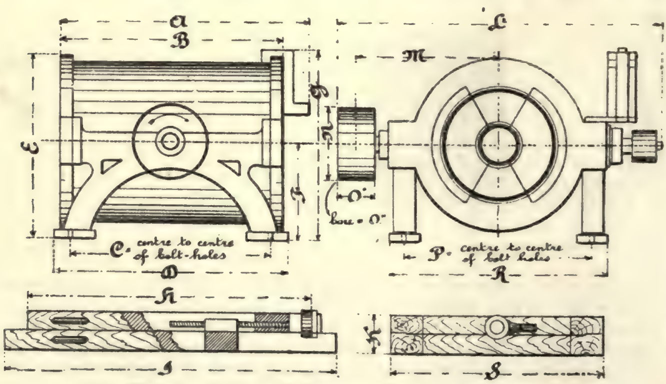


FIG. 41.—Outline of Thomson-Houston dynamo.

of the machine. At the same time, also, the total resistance in circuit being lessened by extinction of lights or removal of resistance, while the current-strength remains constant, the energy represented in the main circuit falls in proportion, and the mechanical energy expended in producing the current falls in nearly the same proportion. Speed variations are compensated for by the regulator controlling the brushes, as in cases of variations of resistance in circuit.

In the machines for 35 and 50 2,000-candle-power arc-lights the ring-armature shown in Fig. 40 has recently been adopted, as it offers many advantages in better ventilation and higher insulation, and, besides, permits of repairs more readily than the older form. The accompanying diagram (Fig. 41) and table give the various dimensions, weights, and capacities of the Thomson-Houston machines:

CLASS.	C	E	H	K	L	M	P	LD	MD
Weight	725	1,450	2,200	3,500	4,025	4,200	5,725	5,200	5,975
Speed	1,250	1,000	950	900	850	850	800	820	820
Lights, 1,200 candle-power	4	9	18	30	....	45	....	50	....
Lights, 2,000 " "	3	6	12	20	25	30	45	35	50
Watts	1,500	3,000	6,000	10,000	12,500	15,000	22,500	17,500	25,000
A	29¾	35½	40¼	43½	45¼	45½	47⅛	46¾	47
B	25¾	31	35½	38	39¾	40	42¼	41¼	41¾
C	25½	32	36	37¼	39¼	39¼	41⅛	39¼	39½
D	27	34	38½	39¼	41½	41⅛	43½	41½	41⅛
E	17¼	23½	28½	32¼	35¼	36½	39¼	36	37
F	9¼	13	14⅝	17¼	18¾	19¼	20⅝	19¼	19¼
G	19¼	25	28¼	33	34⅝	35¼	37½	35½	35½
H	32½	39½	44½	45½	47¼	47¼	50¼	47¼	47¼
I	38⅛	45½	50½	51½	52¼	52¼	55¼	52¼	52¼
K	5⅛	5⅛	5⅛	5⅛	6⅝	6⅝	6⅝	6⅝	6⅝
L	33¾	43¾	50¼	60¾	64½	63½	73	64	64½
M	14¾	19	21½	27¼	28¾	28½	30⅝	27½	28
N	8	10	12	15	15	15	18	16	18
O′	4½	5	6	8	8	8	10	8	10
O″	1½	1⅞	2⅜	2⅞	2⅞	2⅞	3¼	2⅞	2⅞
P	18	23½	26½	33½	36½	36⅞	40⅝	36½	36⅝
R	21	27	30½	38¾	41¼	41¼	45½	41¼	41¼
S	21½	27½	30½	39¼	42½	42½	46¼	42½	42⅛

The Hochhausen Dynamo.—The latest type of this machine, intended for arc-lighting, is shown in Fig. 42. The magnetic frame consists of two field-cores connected by a cast-iron yoke at one end and provided with pole-pieces at the other, which encircle the armature on three sides. The armature, it will be noted, is placed with its shafts in bearings which are on the interior of the machine, so that the armature, as exhibited in Fig. 43, can be entirely exposed. This is facilitated by the pole-pieces, which are hinged, as shown, and which can be turned out so as to show the armature completely, and allow it to be drawn out a sufficient distance for thorough repair, if necessary, without removing the shaft from the journal-bearings. The armature-core is built up of iron wire, insulated by paper, the wire being wound on a cast-iron frame or skeleton having a T-section, which divides the core into two parts. The arms of the spider which holds the armature are insulated from the core and frame, and fit into notches which are cut tapering from both sides toward the center, so as to keep the hole concentric. The coils of the armature, which are rectangular in section, are wound automatically upon the core by an ingenious machine devised by Mr. Hochhausen for that purpose. When placed upon the armature-core the coils are separated on the outer circumference by wooden wedges, which are secured to the cast-iron skeleton of the armature, and they are held in position by sections of fiber-band which are screwed into the wooden wedges just referred to.

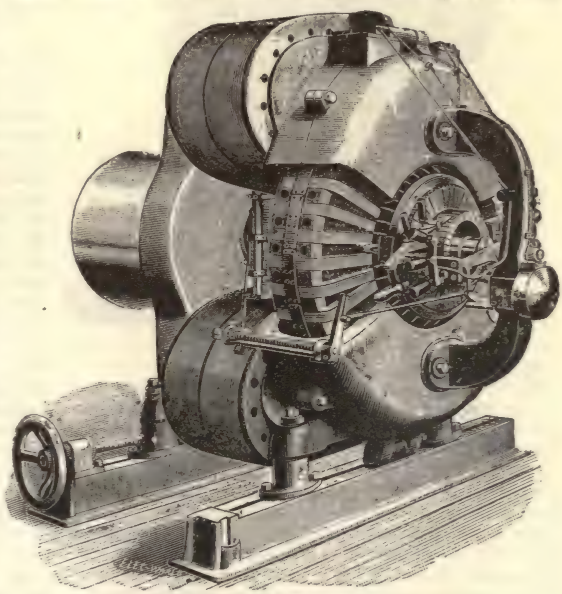


FIG. 42.—Hochhausen dynamo.

The regulation of the machine is a development of the methods heretofore employed by Mr. Hochhausen, and is very ingeniously carried out, consisting in the shifting of the brushes in conjunction with a regulating resistance, both of which are simultaneously operated

by an old device originated by Mr. Hochhausen—namely, a small auxiliary motor. This motor, which is entirely hidden from view, is situated in the hub-like projection bearing on the arms which span the two pole-pieces beside the end of the armature-shaft, and which might be mistaken, except on closest scrutiny, for the bearing of the shaft. This small motor is fixed in a magnetic field, which is produced by attaching the cast-iron arms shown, to each pole-piece and bringing them together, so as to surround the armature of the small motor. It might be thought for an instant that such a bridging of the magnetic circuit would take a large number of the magnetic lines of force away from the armature, but this has been provided for by mounting the cast-iron arms, not directly on the pole-pieces, but by separating the two iron surfaces by a good thickness of hard rubber, so as to make a considerable break in the magnetic circuit. The magnetism passing through the arms, therefore, is very weak, but, nevertheless, sufficiently strong to produce a field for the small regulating-motor, which acts with the greatest promptness. The regulation of the machine is effected in a very ingenious manner by means of a wall-regulator, which serves as a controller for the regulating motor. The method employed is very clearly shown in the diagram, Fig. 44. Here, it will be seen, $M B$ are the main brushes mounted upon a rocker-arm, which is provided with a circular rack which meshes with a pinion attached to the end of the shaft of the small motor-regulator. Starting from the positive terminal of the machine P, the current is led to the binding-post 4 on the wall-controller, and from there passes into the controller-magnets $M\ M$. After traversing these magnets the current enters the armature A, and after passing through the resistance R^1 goes to line and the external circuit to the negative terminal N and main brush of the machine. It will be noted, however, that the end of the controller armature A bears against two contact-points $C\,C^1$, which are connected through points 2 and 3 to the brushes of the small regulating motor on the machine. At the same time the two latter circuits are tapped at points P^2 and P^3, and connected through German-silver resistances $R^3\,R^2$ to the terminal 1. Now, the regulating magnet $M\,M$ is so adjusted that when the normal current passes over the line, the armature A stands horizontal and makes contact with both points $C\,C^1$, which are fixed at the end of the lever B. The current entering the armature A from the magnets $M\,M$, therefore, besides passing to line through the resistance R^1, has two other paths open to it through contacts $C\,C^1$ to the brushes of the small regulating motor *via* points 2 and 3. But it will be remarked that the currents in these two circuits are in the same direction, when they meet at the regulating motor opposite each other, with the result that they have no effect on the little motor, the armature of which remains stationary. It will also be noted that a part of the regulating current passes to line through R^2 and R^3. Now, if from any cause an increase of current takes place above the normal, the armature A of the wall-controller is drawn down out of its horizontal position, by which action the contact at C is broken, while that at C^1 is still maintained. The regulating current now has only one path open to it, from C^1 to 2 2, etc., to the left-hand brush of the motor-regulator, thence through the armature to the other brush to points 3 3 P^3, and out to line through the resistance R^2. This affords a complete and continuous path for the regulating current, and the motor armature at once starts to revolve and to turn the brushes of the machine in the corresponding direction for cutting down the current; at the same time the rod $F\,F$ acts upon the field-switch S, which assists the brushes in reducing the current by cutting out sections of the field-magnets. When the normal current has again been established the controller armature re-establishes contact C and the regulating motor stops. A diminution of the current from the normal causes the breaking of the contact C^1, which sends the regulating current through the motor in the direction opposite to that just described, and with a corresponding effect. It will be evident that at all times the resistances $R^1\,R^2$ and R^3 are in circuit, and as the last two points form constant shunts to the points C and C^1, no sparking whatever takes place when contact is broken at either of those points. The result of this is,

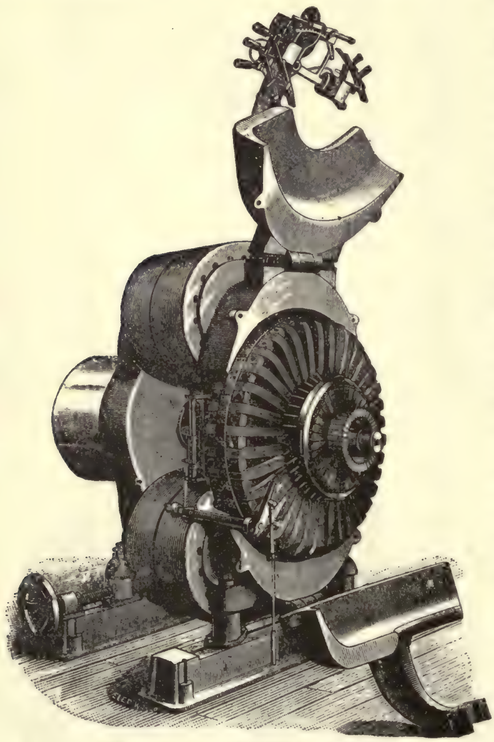


FIG. 43.—Hochhausen dynamo.

that upon any variation in the current, not only are the brushes revolved in a corresponding direction by the regulating motor, but, as will be noted, the field-switch *S* is operated, to cut sections in or out, by means of the connecting arm *F F*; both these methods of regulation, acting in conjunction, serve to bring the machine instantly into its normal state. The switch S^1 is provided for the purpose of cutting out the regulating motor when adjusting the position of the magnets *M M*, while the switch S^2 is employed for short-circuiting the field-magnets when shutting down the machine. As the potential employed on the largest-sized machine approaches the neighborhood of 5,000 volts, extra precaution must be taken for insulation of the various parts, which is made specially necessary by the static charge, which has opportunity to accumulate from the friction of the belt. The jumping of the spark, due to this accumulation, is apt to be followed by the current from the machine. To avoid this the armature is thoroughly insulated with mica from the spider which holds it, and the bearings are also insulated from the main body of the dynamo, and the latter, again, from the iron skids upon which it is mounted. Various sizes of this machine have been built—the largest, designed for 125 1,200-candle-power lamps, or for 100 2,000-candle-power lamps. The diameter of the armature of this machine is 30 in. and has 36 coils wound upon it, each 8 in. square. One hundred and sixty pounds of No. 17 B. & S. wire are wound on the armature for the 1,200-candle-power lamps, which require seven ampères, and the same weight of No. 16 wire where the 2,000-candle-power lamps are employed, which take ten ampères. The speed of the machine is 700 revolutions per minute, and its total weight 5,500 lbs. The field is wound with 1,300 lbs. of No. 8 wire, divided into two sections. One of these is wound unbroken, while the other is tapped at equal intervals by 20 wires, which are connected to the field-switches and controlled by the brush-rocker in the manner described above. The second size of this machine constructed is designed for 50 lights of 2,000 candle-power each, and has 90 lbs. of wire on the armature and 870 on the field. The third size, designed for 30 lights, has 55 lbs. of wire on the armature and 400 lbs. on the field.

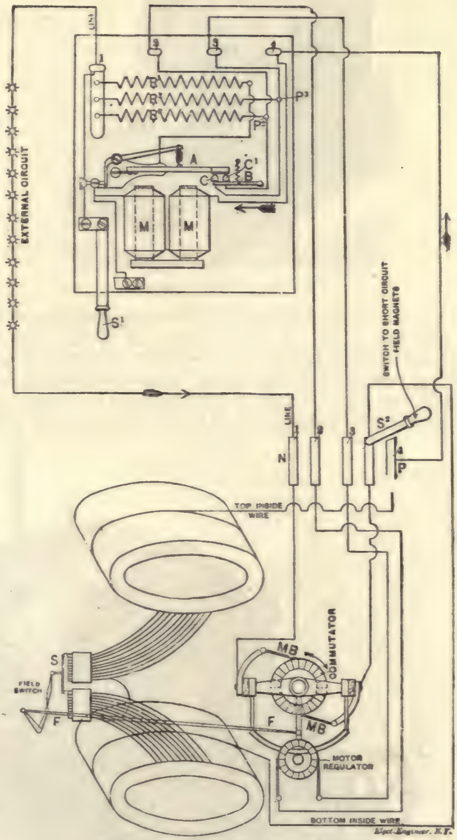


FIG. 44.—Regulating apparatus.

The general appearance of the machine, it will be noted, is exceedingly compact, and the open construction adopted allows of ready access to every part for examination and repair, if necessary. The machines have already been placed in several stations, where their operation has been attended with marked success. The following data refer to a machine of this type designed to operate 100 arc-lights in series: Current, 10 ampères; E. M. F., 5,000 volts; resistance of field, 14 ohms; resistance of armature, 13 ohms; ampère turns in field, 42,400; ampère turns in armature, 40,500; number of sections in armature, 36, of 225 turns each; size of wire on field, No. 8 B. & S.; size of wire on armature, No. 15 B. & S.; speed, 750 revolutions per minute; weight, 6,300 lbs.

The Sperry Dynamo.—In the rotary movement of a ring-armature between opposite external pole-pieces, the lines of force, according to one theory, enter the armature-core and traverse the coils, producing an equal magnetic effect on every portion of each coil, interior as well as exterior. According to another theory, only the exterior portion of the coils cuts the lines of force; the interior portion, as well as that on the ends, being practically idle, serving only as a conductor of the electricity generated in the exterior portion. To bring this idle portion into action, the field-magnets of the Sperry dynamo are constructed with interior as well as exterior pole-pieces, the flat ring-armature being nearly inclosed between them, by which means, it is claimed, about 92 per cent of the armature-wire is rendered effective, while, without interior pole-pieces, only 30 to 54 per cent becomes effective. Fig. 45 represents the field-magnets complete. They consist of four magnets, the four cores being attached to a heavy iron yoke. From each core two pole-pieces, like the tongs of a tuning-fork, project horizontally, eight in all—four interior and four exterior—the two sets being arranged in two concentric circles, as shown, leaving an annular space between them. The armature, shown in Fig. 46, rotates in this space, its position being reversed, and its shaft passing through the

center of the magnet-yoke. Its core has the same construction as that of others already described—thin, flat, sheet-iron rings, insulated with paper and bolted together, without air-

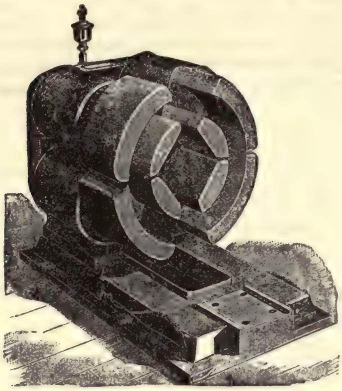


FIG. 45.—Field-magnet.

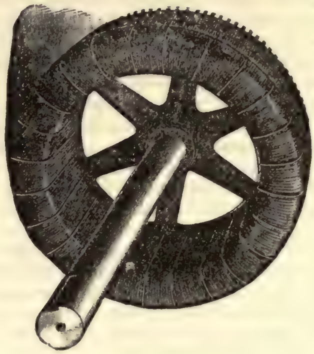


FIG. 46.—Armature.

spaces. It is attached at the commutator end to a brass support called the spider, connected with the shaft. It is series-wound, in one closed circuit, with insulated copper wire of suitable size, the coils being connected by radial arms with the commutator in the usual manner; the ring complete being 8½ in. wide in the 35-arc-light machine. The shaft with the armature attached can be moved horizontally by means of a screw, and the armature drawn out of the inclosing pole-pieces, and consequently out of the magnetic field, to any required extent, thereby reducing the magnetic and electric intensities. A special feature of the new Sperry dynamo is the automatic regulator. The brushes consist of overlapping flat copper strips attached to a movable yoke, which is connected by means of an arm to an electro-magnetic regulator placed in the lamp-circuit. Any variation in the electrical resistance of the lamp-circuit operates the keeper of the electro-magnet. By an ingenious ratchet-and-pawl device this movement adjusts the current of the dynamo in proportion to the variation in the resistance of the lamp-circuit. It is claimed that 75 per cent of the total number of arc-lamps may be instantly switched out without the least danger to the machine. Fig. 47 shows the machine in perspective.

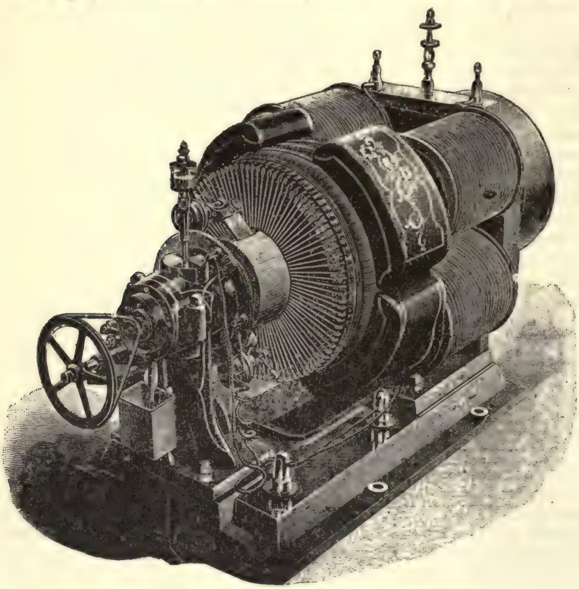


FIG. 47.—Sperry dynamo.

Fig. 48 is a diagram of the *Waterhouse* dynamo, with a closed-circuit armature A. Fig. 49 shows the Waterhouse dynamo, type No. 3, on which the regulator is used. On the commutator C are three brushes: a and b are the main circuit brushes, and c the auxiliary brush. From the positive brush a the current passes on the conductor around the field-magnets F to the resistance R. The current from the auxiliary brush c passes directly to resistance R, leaving the field-magnets out of circuit. The currents from both circuits (field and local) join at R, and pass to the lamps, the current on the lamp-line being the sum of the two. The amount of current in the field and local circuits is in proportion to the resistance R in each. The brushes have a fixed position. There is in every dynamo a point of maximum commutation on the armature which changes with the resistance on the lamp-line, moving with the rotation (toward brush c) when the resistance decreases, and back when it increases. This affects the current in the local and field circuits as follows: When lights are turned out, the line resistance is decreased, and the maximum point moves forward and forces more current out of brush c and less out of brush a. This reduces the current in the field-magnets and the E. M. F., and consequently the power required to operate the dynamo, but the current on the

lamp-line remains constant because the local circuit is increased proportionally to the decrease of the field circuit. The remaining lamps, therefore, retain their full brilliancy, while the current can not increase and destroy the apparatus. The regulator is illustrated diagrammatically in Fig. 48. It is operated by the slide, which is controlled by a solenoid. Any tendency of the current to increase raises the contact, and the result is a decrease of resistance in the local circuit and an increase of resistance in the field circuit. More current will therefore flow through the local circuit and less through the field circuit. The generating capacity of the dynamo is instantly reduced, and any tendency to produce a current above the standard is overcome. Should the tendency of the current be to decrease, say by a reduction of the speed of the armature, the slide lowers, increasing the resistance in the local and reducing it in the field circuit. More current will then flow around the field-magnets and less out on the local circuit. The generating capacity of the dynamo will therefore increase to maintain the current at standard.

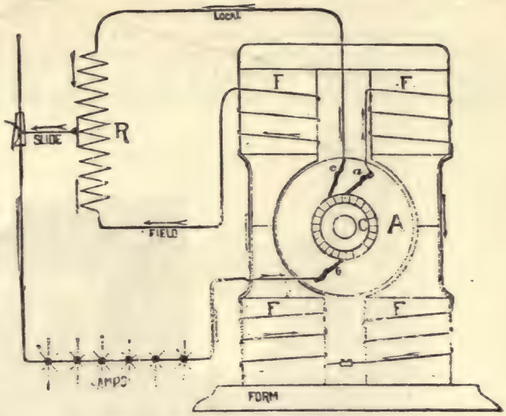


Fig. 48.—Waterhouse dynamo-connections.

It was stated above that regulation could be effected in a dynamo by shunting the lines of force around the armature. This has been carried out in the *Goolden and Trotter* dynamo (Fig. 50). The double-magnet type of dynamo is very suitable for this purpose, for one half of the machine may be constantly magnetized to the desired point of saturation, while the other half acts as a keeper. The former may be called the constantly magnetized limb, and the latter the keeper. They are similarly wound with exciting coils. If the constantly magnetized limb is fully excited by the usual current through its coils, and no current is passed through those of the keeper, the latter will act as a magnetic shunt, and nearly all the lines of force will pass round and round in a closed circuit of iron ; little or no polarity will be found at the pole-pieces, and there will be a minimum effect on the armature. By allowing a weak current to pass round the keeper, the diversion of the lines of force through it will be partially obstructed, and the rest will take their usual path through the armature. With a certain strength of current this obstruction will be complete, no lines will pass in either direction, and the magnetic effect is the same as though the keeper had been entirely removed from the dynamo. The strength of the field and its action on the armature is the same as though the dynamo were provided with one magnet only. If now the current through the coils on the keeper be increased beyond its neutral point, it will assist the permanent magnet, the lines of force in the former will be reversed, and finally, when the whole current passes round it, the volts are at the maximum, and the dynamo works as an ordinary series-wound machine. It was soon found in practice that, owing to the complete magnetic circuit formed by the pair of magnets, the changes in the strength of the field were somewhat sluggish. This was remedied by making a gap in the magnetic circuit, by boring out the yoke on the side where the magnet-bars passed through, and bushing them with brass, using brass washers also on the ends of the bars and under the nuts. A practical application has been made of this method for

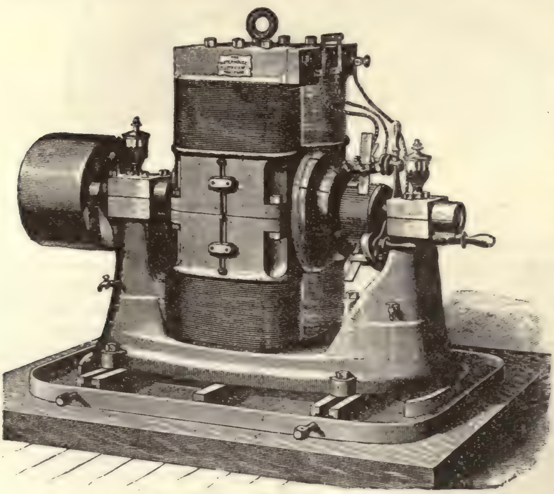


Fig. 49.—Waterhouse dynamo.

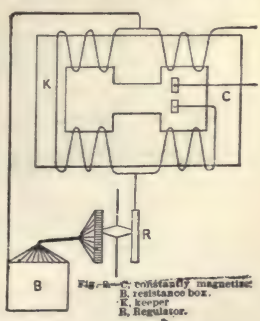


Fig 50.—Goolden and Trotter dynamo.

the purpose of running Bernstein incandescent lamps arranged in series, and a dynamo controlled on this system by an automatic regulator enables the lamps to be extinguished by short-circuiting.

The Edison Dynamo.—The early form of the Edison dynamo consisted of a drum-armature built up of laminated iron, and revolving in a field consisting of one or more long cylindrical electro-magnets, according to the output of the machine. The most powerful machines of this type were those constructed for the first Edison central stations in Pearl Street, New York, 1882, and Milan, Italy, illustrated in Fig. 51.

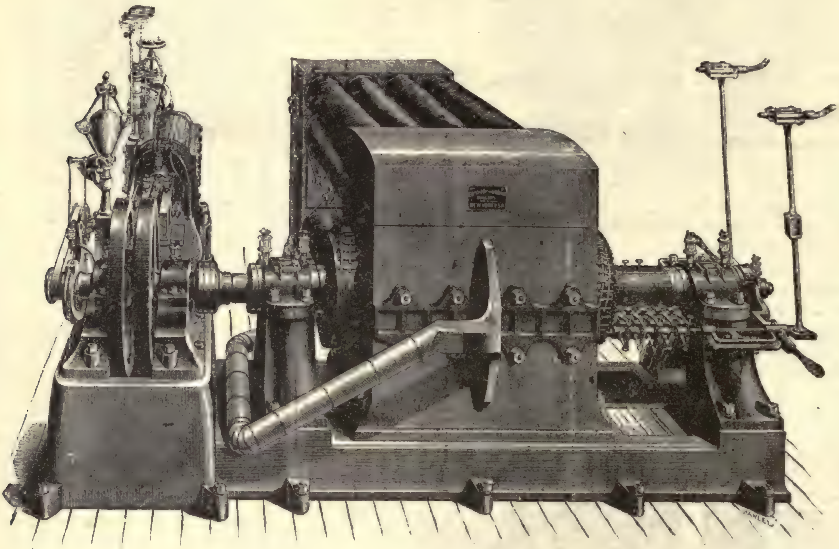


FIG. 51.—Edison dynamo.

The armatures of these machines are 27·3 in. in diameter, and 61 in. long. The shaft is of steel, 7$\frac{3}{4}$ in. in diameter, and of a total length of 10 ft. 3 in. Provision is made for an air-blast to keep the armature cool. The armature is driven direct by a Porter-Allen steam-engine running at 350 revolutions per min., and having a piston-speed of 133 ft. per min. Machines of this type are still operated in the Edison station, Milan, Italy, but their use has been abandoned in New York, on account of the increased efficiency of the improved type of Edison machine illustrated in Fig. 52.

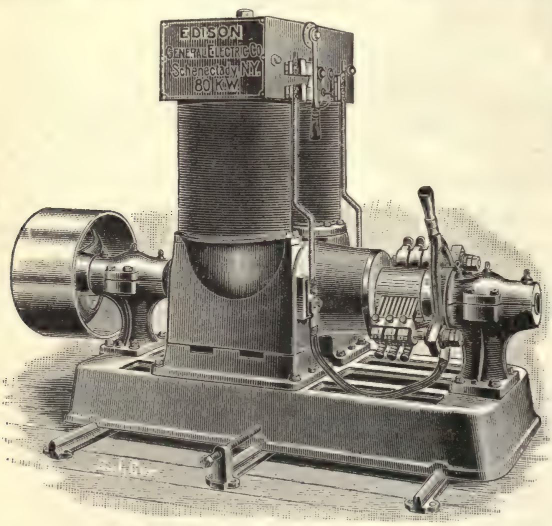
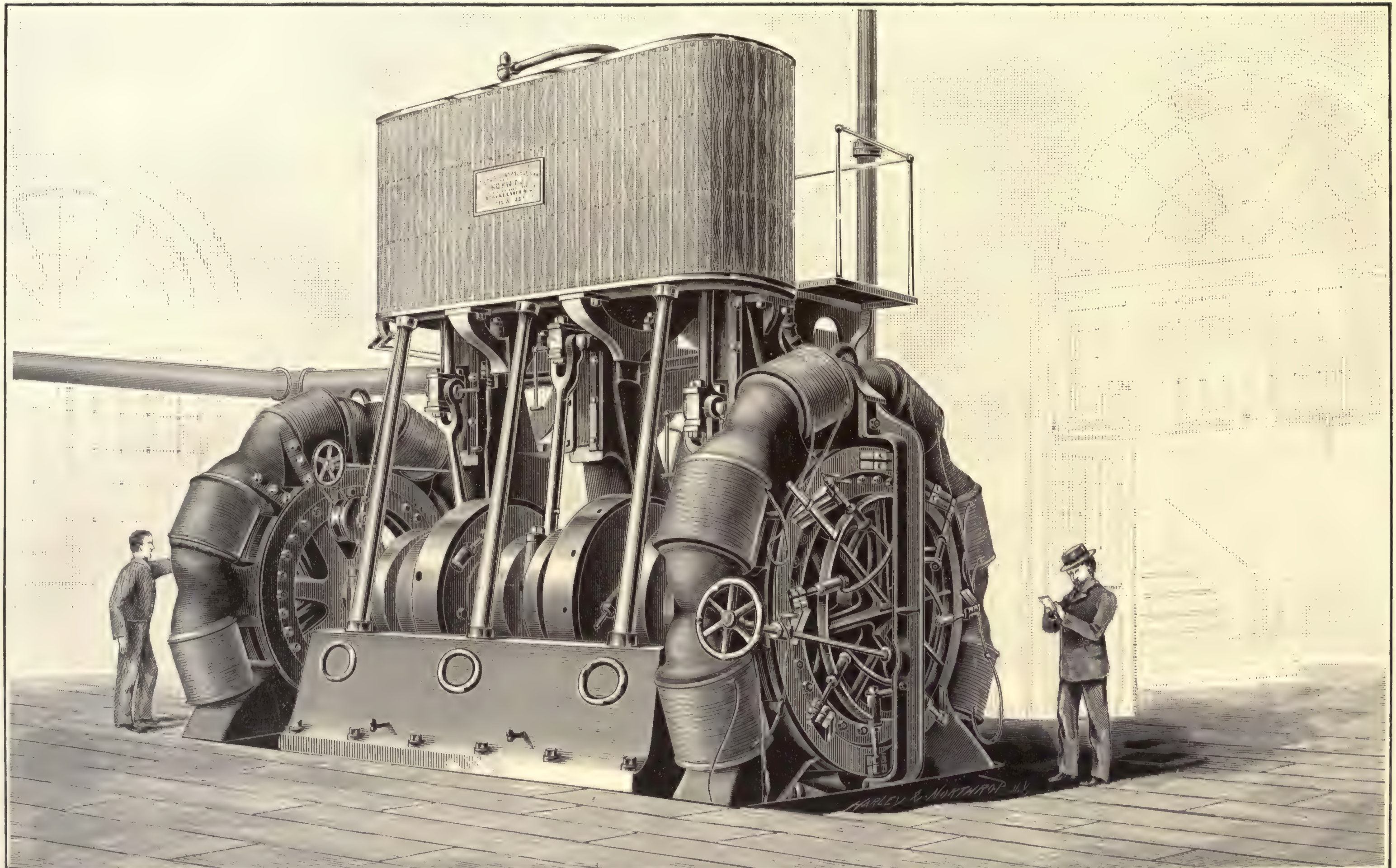


FIG. 52.—Edison dynamo, improved.

In this machine the magnets are greatly shortened, and consist of circular wrought-iron cores mounted on heavy cast-iron pole-pieces, which surround the armature. The machine rests upon a cast-iron bed-plate, which carries the armature bearings, but in order to avoid short-circuiting of the magnetic lines around the armature, which would ensue if the pole-pieces rested directly in contact with the iron bed-plate, the latter is separated from them by the zinc castings shown. The magnetic yoke between the tops of the field-magnets consists of a massive block of wrought iron, and upon it are mounted the contacts and switch for opening and closing the circuit to the machine.

These machines are built in sizes ranging from a few horse-power to over 250 horse-power,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and the following data refer to three sizes, the *K. W.*, or Kilowatt, being equivalent to 1·33 horse-power:

	SIZE OF MACHINE.		
	6 K. W.	25 K. W.	100 K. W.
External diameter of armature in inches	$6\frac{5}{8}$ in.	$9\frac{3}{4}$ in.	$17\frac{5}{8}$ in.
Speed of machine as dynamo revolutions per minute	1,800 revs.	1,300 revs.	650 revs.
Number of commutator sections..........	58	66	48
Number of turns per section........	3	1	1
E. M. F. generated........	125 volts	125 volts	125 volts
Resistance of field-winding shunt machine........	54·4 ohms	37 ohms	16·4 ohms
Ampère turns in field-winding at full load........	8.650	14,300	24,250
Diameter of wire on field-winding........	·042 in.	·065 in.	·109 in.
Resistance of armature	·116 ohm	·0167 ohm	·00515 ohm
Gauge of wire used for winding armature	No. 12 B. W. G.	Two No. 8 B. W. G.	Four No. 3 B. and S.
The weight of machine complete	830 lbs.	3,570 lbs.	16,200 lbs.

Fig. 53 shows the general type of Weston machine for arc and incandescent lighting. Probably the most strikingly distinctive feature of the Weston machine is the sectional arma-

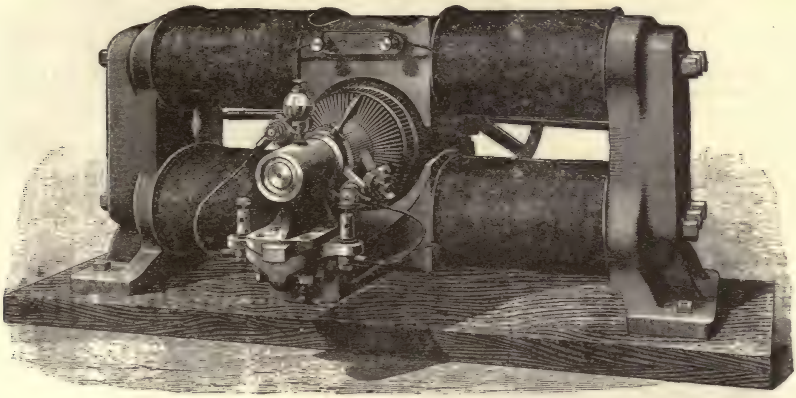


FIG. 53.—Weston dynamo.

ture. The armature-core (Fig. 54) is built up of iron disks of the form shown. These are secured together upon the armature-shaft, but separated somewhat from each other, so as to leave spaces between them. These spaces serve to break up the continuity of the core, and thus prevent the formation of induced currents; they also form ventilating spaces. By a very ingenious arrangement, the armature is made to act as a centrifugal blower, to maintain a circulation of air through the core and about the coils, and thus whatever heat may be generated in them is dissipated. The coils are spread apart, where they pass across the heads of the armature, by flanged plates (shown somewhat removed from the head of the armature in Fig. 54), so as to leave an opening about the shaft for the admission of air, which is taken into the interior of the armature and thrown out between the coils by centrifugal force. With a sectional armature and this system of ventilation, no trouble whatever is experienced from heating of the core or coils. The armature complete is shown in Fig. 55.

FIG. 54.—Weston armature.

The cores and pole-pieces of the field-magnets are made very heavy, so as to maintain an extremely intense field with comparatively little expenditure of current-energy, and the pole projections on the armature being almost directly in contact with the pole-pieces, concentrate the lines of force of the field directly upon the armature. All of these features of construction contribute to produce the requisite electromotive force with very low internal resistance and low speed.

In a Weston machine, de-

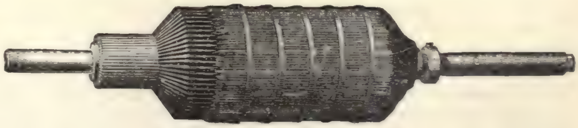


FIG. 55.—Weston armature.

signed for 200 incandescent lamps, 199 could be turned out without materially affecting the brilliancy of the remaining one. The data of this machine are as follows: Weight, 2,836 lbs.; length, 62·5 in.; breadth, 53 in.; height, 25·75 in.; resistance of external circuit, 0·4 ohm; resistance of armature, ·008 ohm; resistance of field-coils, 24·1 ohm; E. M. F., 67 volts; number of revolutions per min., 960; diameter of armature-wire, 0·24 in. The ratio of armature to shunt resistance in this case was therefore 1 to 3,000. This high rate is, however, rarely attained.

Fig. 56 illustrates the *Thomson-Houston Dynamo* for incandescent lighting. It resembles in general design the arc-machine; its distinguishing feature, however, is the method employed for obtaining constant potential automatically without the use of external resistances. This is accomplished by means of a set of "series-coils" placed at an inclined position around the armature, as shown, which react upon the armature so as to maintain the point of commutation fixed at all loads.

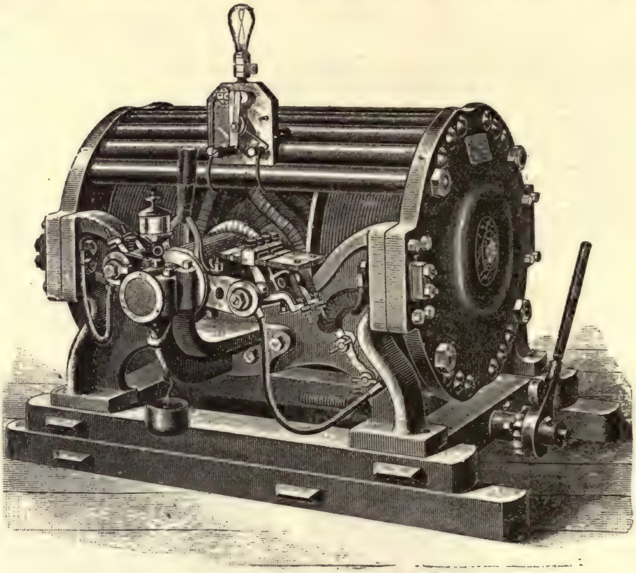


FIG. 56.—Thomson-Houston dynamo.

Fig. 57 shows the *Eickemeyer Dynamo*, which claims attention on account of its novel construction. The object sought to be obtained by the inventor is to concentrate the full exciting force of the field-coils upon the armature-core, and he accomplishes this by encircling the armature-core with an exciting helix, and then inclosing the whole within an iron shell. The latter is provided with pole-faces, and thus completes the magnetic circuit which includes the armature-core and the cheeks.

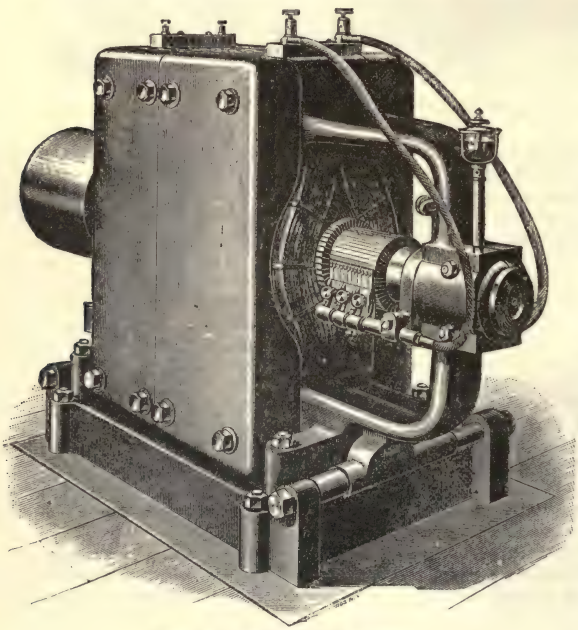


FIG. 57.—Eickemeyer dynamo.

Fig. 58 shows a longitudinal section of one form of the machine, and Fig. 59 a transverse section with the armature removed. It will be seen that the shell of iron inclosing the armature is built up of a laminated mass of sheet-iron, to which end-pieces of cast iron are added, the whole being bolted together. The iron sheets are stamped out circularly with a longitudinal extension on the upper and lower halves. The rectangular space thus formed is occupied by the field-coils, which are wound in the same direction as the wires of the armature, and are divided so as to leave a space for the passage of the armature-shaft. The armature is placed within the exciting coils, and is completely surrounded by the coils above and below and by the iron at the sides. The magnetic circuit thus formed is a complete one, and not the slightest evidence of external magnetism is perceptible. As regards the output of this machine, it may be remarked that Mr. Eickemeyer has made the experiment of plac-

ing the armature of an old form of machine within the field, such as he uses, and by employing the same amount of field-wire as was used on the older form he succeeded in increasing the out-put of the armature nearly twice. More recent machines are built of solid cast steel.

In the *Kennedy Dynamo* (Fig. 60) the field-magnet is made of three pieces, with only one field-bobbin. The core of the bobbin is made of hammered scrap-iron, and measures 10 in. in diameter and 14 in. in length; the pole-pieces are of soft cast iron, and are of much greater

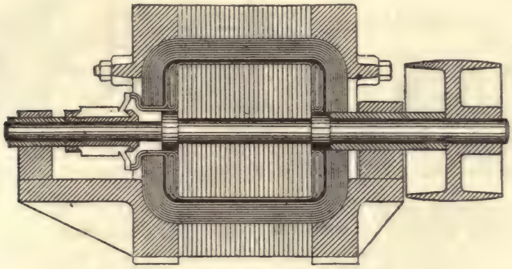


FIG 58.—Section.

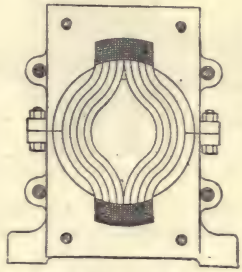


FIG. 59.—Section.

cross-section than the core of the bobbin. This construction has the advantage of simplicity, combined with compactness and low magnetic resistance. The armature is built of charcoal-iron disks, and the core is turned true, outside and inside, and mounted on metal spokes on a steel shaft. The outsides of the armature are usually turned up true on the shaft. The armature-core of this machine is 12 in. long, 10 in. in diameter outside, and 6 in. inside diameter, the depth of core being thus 2 in. The armature is wound with flat wire 5 mm. by 3·5 mm., one layer outside. The current allowed for this armature running constantly for long runs is 90 ampères. The commutator is made of solid drawn copper sections, insulated with mica, and is of large size. The brushes are adjustable in all directions, and the pressure on the commutator is adjusted by springs. The brushes require a slight adjustment for varying loads, but at a speed of about 900 revolutions the machine gives 102 volts at the terminals. According to the tests of Prof. Andrew Jamieson, the dynamo gave an output of 10,850 watts, or 108·5 ampères, and 100 volts at 620 revolutions per minute. The peripheral speed of the armature is 1,900 ft. per minute. The following are the data of construction and operation of the machine: Resistance of armature, warm, = ·04 ohm; resistance of magnet-shunt, warm, = 20 ohm; resistance of magnet main coil, warm, = ·03 ohm; current in working circuit = 108·5 ampères; current in shunt-magnet coils = 5 ampères; difference of potential at dynamo-terminal = 100 volts; difference of potential at brushes = 103 volts; speed in revolutions per minute = 620; temperature of air = 60° F.; highest temperature of armature = 140° F.; highest temperature of magnet-coils = 125° F.

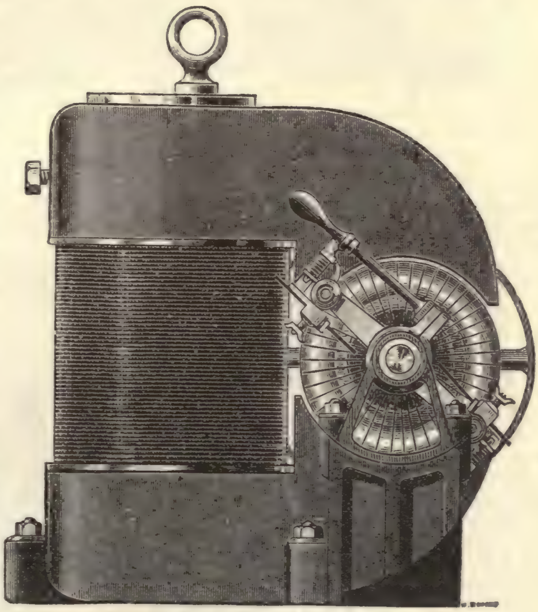


FIG. 60.—Kennedy dynamo.

The *Mather and Hopkinson Dynamo*, an excellently designed machine, is illustrated in Figs. 61 and 62. The armature, designed by Dr. J. Hopkinson, F. R. S., and Dr. Edward Hopkinson, is a modified Gramme, with low resistance and careful ventilation. The collector is unusually substantial, and consists of 40 bars of toughened brass insulated with mica. It is usual in these machines so to shape the pole-pieces that there is a smaller clearance opposite the highest and lowest points of the armature; this concentrates the magnetic field, and helps to prevent its distortion by the armature-current. In a 24-unit machine (designed for 300 lamps) of this pattern the armature-cores are 12 in. long and 12 in. in diameter, with 120 turns of wire. The resistances are: Armature, ·023 ohm; shunt, 19·36 ohms; series-coil,

·012 ohm. With a speed of 1,050 revolutions per minute the current was 220 ampères, the machine being nearly self-regulating for 111 volts. This machine is known as the "Manchester" dynamo. Its efficiency is 90·9 per cent.

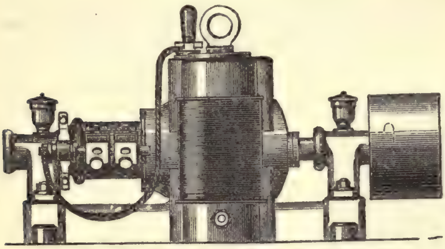


Fig. 61.—Mather and Hopkinson dynamo.

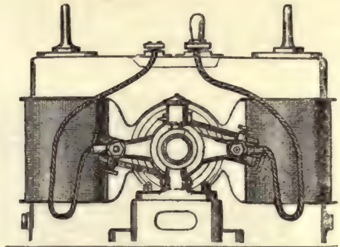


Fig. 62.—"Manchester" dynamo.

The *Brown Dynamo* (Fig. 63), designed by C. E. L. Brown, of the Oerlikon Works, near Zurich, Switzerland, closely resembles the "Manchester" type (Fig. 62), but is even more massive. The illustration represents the machine designed to give 450 ampères at a 115 volts at 350 revolutions per minute. The dimensions of it are as follows: Diameter of ring, 61·4 cms.; length of ring, 55 cms.; length of shaft, 196 cms.; total height of machine, 120 cms.; wrought-iron cores, 60 cms. long, 40 cms. diameter; cast-iron yokes, 30 cms. thick. 44 cms. broad; diameter of pulley, 60 cms.; total weight, 6.5 tons; ampère turns at full excitation, 35,000.

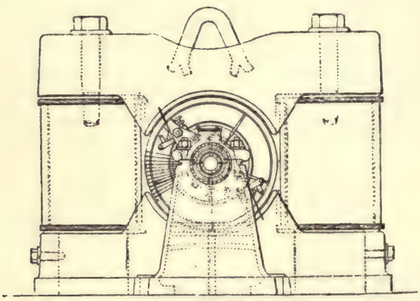


Fig. 63.—Brown dynamo.

The armature of Brown's dynamo differs in one respect from those of the preceding machines. It is built up of thin iron disks, but these, instead of being toothed as in the Pacinotti forms, are perforated with a peripheral series of holes, as in the Wenström dynamo, to receive the armature conductors, which lie thus about 1 mm. below the periphery. This construction reduces the magnetic resistance of the air-gap to an exceedingly small quantity, and there is no tendency, as with most toothed armatures, to undue heating of the pole-pieces.

Fig. 64 represents the general type of incandescent machine designed by Mr. William Hochhausen for the Excelsior Electric Co. The armature is supported by two arms, which project from the neutral points of the magnet-frame at its base. The magnet-cores are composed of solid wrought iron. The following data give a good idea of the electrical design of the machine capable of feeding 600 incandescent lamps: Current, 360 ampères; E. M. F., 110 volts; resistance of field, 18 ohms; resistance of armature, ·005 ohm; ampère turns in field, 22,420; ampère turns in armature, 8,820; size of conductors on field, No. 10 B. & S.; size of conductors on armature, bundle of four No. 5 B. & S. wires; number of sections on armature, 49, of one turn each; speed, 750 revolutions per minute; weight, 6,500 lbs.

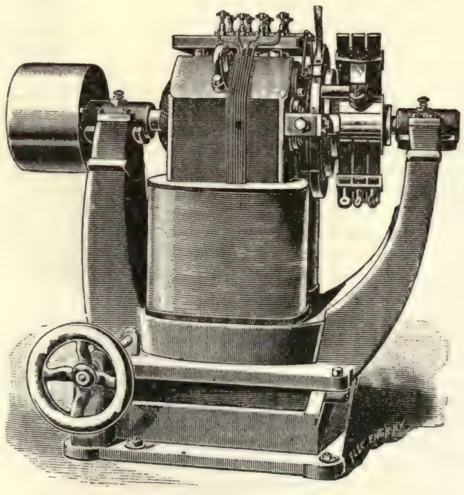


Fig. 64.—Hochhausen dynamo.

Dynamos for Electrolytic Purposes.—These machines do not differ materially from the general type of generators, but are specially constructed for delivering heavy currents at very low voltage. In these machines it is specially desirable to obtain as low an internal resistance in the armature as possible, and frequently they are wound with heavy copper bars. The latest form of Hochhausen's plating-machine resembles closely the type of his incandescent machine, Fig. 64. The machine is so wound and connected that it can be made to deliver two potentials with corresponding strengths of current. The following table gives the capacity and dimensions of these machines in inches:

NUMBER.	Volts.	Ampères.	Horse-power.	Floor-space.	Height.	Pulley.	Speed.	Weight.	Lbs. of copper deposited per hour.
81	2·5 5	250 125	1	21¼ × 16⅝	14⅝	4 × 2	2,100	137	4
82	2·5 5	500 250	2	22¾ × 19¼	18¾	5 × 2½	2,000	270	8
83	2·5 5	1,000 500	4	29¾ × 22¼	20⅞	6 × 3	1,800	450	16
84	2·5 5	2,000 1,000	8	37 × 32½	29	8 × 5	1,600	930	32
86	2·5 5	6,000 3,000	22	52¾ × 29	33	14 × 10	1,000	2,500	96
88	16	2,400	55	66 × 37	45	20 × 12	800	4,000	288
90	16 32	5,000 2,500	115	89½ × 52	56	30 × 16	600	7,000	576

The following data relate to a Hochhausen machine capable of reducing and depositing 7,000 lbs. of copper per day of 24 hours: Current, 2,400 ampères; E. M. F., 16 volts; resistance of field, ·285 ohm; resistance of armature, ·00025 ohm; ampère turns in field, 39,300; ampère turns in armature, 10,800; number of sections in armature, 9, of one turn each; size of conductors on field, No. 10 B. & S. wires in multiple; size of conductors on armature, 36 No. 8 B. & S. wires in multiple; speed, 700 revolutions per minute; weight, 6,800 lbs.

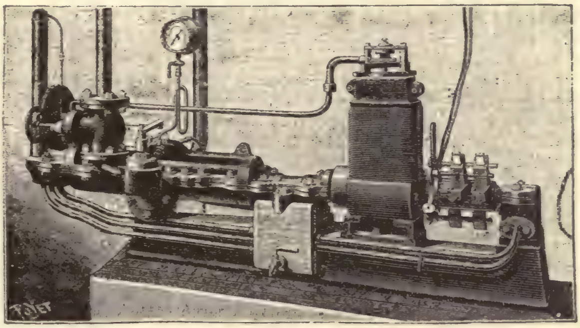


FIG. 65.—Turbo-electric generator.

The *Turbo-Electric Generator* of Messrs. Clarke, Chapman & Parsons has been specially designed for compact marine installations. The combination consists of a steam-turbine, or rotary engine, of novel construction, connected directly with a dynamo. Fig. 65 shows the machine in perspective, and Fig. 66 shows the engine taken apart, so as to expose the interior of the "turbine."

As will be seen, the steam enters the barrel at the center, passes through the succession of turbines to either end, whence it passes through a steam-way cast in the lower part of the barrel, and finally exhausts at the center just below the admission port. The spindle is of steel and carries a number of brass disks, reduced near the periphery, where the blades are cut to half the thickness they possess at the center. The projecting ring thus formed has helical teeth cut upon it, constituting the moving blades, the pitch of the teeth varying along the length of the barrel to allow of the expansion of the steam. The disks are made of such diameter as just to turn freely with the spindle within the barrel without risk of contact with the interior of the rings which carry the fixed blades. The spindle is made very stiff, so as to allow the clearance to be made exceedingly small, as it is found that the loss of power due to the friction of the spindle and its bearings is exceedingly small, and it is very desirable to prevent, as far as possible, the passage of steam between the barrel and the disks. Between each of these disks there is an annular wheel, with helical teeth, corresponding to those on the disk, but sloping in the other direction. These form the fixed or guide blades. The annular wheels are fitted closely within the barrel, the teeth projecting from one half of their width only, and it is within the smooth cylindrical portions of these annular wheels that the moving blades or teeth of the disks actually turn. The barrel thus contains a double series of sirens very similar in principle to Helmholtz's double siren, only that the axis is horizontal instead of vertical. The holes in the disks are cut around the periphery, and there are a great number of pairs of disks, sometimes 45 or more, on each side of the center. One of the most ingenious features of the generator is the magnetic governor. The field-magnet is shunt-wound, but not nearly

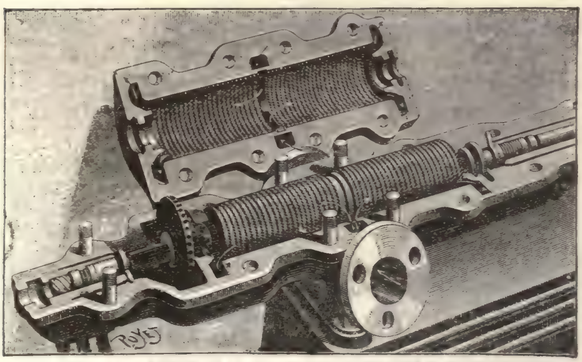


FIG. 66.—Turbo electric generator—details.

saturated. Hence, any increase of the E. M. F. of the dynamo increases the magnetism of the field-magnet. Above the yoke is pivoted a bent iron bar, which is attached to a spring similar to the hair-spring of a watch, so that this bar is mounted exactly like the balance-wheel of a watch. Projecting from this iron bar, at an angle of 45°, is a gun-metal fork, the extremities of which are formed with sharp edges and move immediately in front of the opening of the small copper tube which is seen in the upper part of the figure. This tube communicates with a small circular bellows, shown above the left end of the turbine barrel. The bellows are kept distended by a spring, but a small turbine on the spindle of the motor tends to exhaust the air and make the bellows collapse under the atmospheric pressure. The throttle-valve which regulates the steam-supply is connected with the movable back of the bellows, the rod passing through a gland in the fixed front. When the iron bar above the field-magnet is inclined about 45° to the axis of the machine, the end of the copper tube is fully open, and air enters the bellows as fast as it is exhausted by the turbine, and the throttle-valve remains fully open. If the E. M. F. increases, the iron bar turns in the direction of the lines of force against the constraint of the "hair-spring," the end of the fork closes the air-pipe, the bellows collapse under the exhaust of the little turbine, and the steam is shut off by the throttle-valve. The action of this governor is so prompt, the moment of inertia of the moving parts of the machine being so small that nearly all the load may be turned off the machine with scarcely a perceptible change in the brightness of the lamps remaining. It will be seen from the figure that the commutator is made of very great length. The brushes are of wire and press nearly "end on" to the commutator. The four brushes can be shifted into any position, so as to keep the wear of the commutator even. The armature is of the cylinder type. The core is built up of thin charcoal-iron plates, separated from each other by thin disks of paper. The disks are clamped up tight by two brass disks threaded on the shaft. The coils, which are laid in channels cut in the iron, are 30 or 40 in number, of stranded or solid copper wire, and each makes one complete turn. The whole is bound round with steel piano-wire. The commutator-segments are connected each to the ends of two adjacent coils, connected up in parallel. There are, therefore, 15 or 20 commutator-bars. The speed varies, according to the size of the machine, from 9,000 to about 10,000 revolutions per minute. The loss of power in the armature and field-magnet coils on the large machines amounts to only about 1½ per cent, the high speed allowing exceedingly small resistance to be employed in the armature. A machine with an output of 32 electrical horse-power in the outer circuit is about 10 ft. 6 in. in length and 1 ft. 6 in. in breadth. A small machine, running a lamp of 1,000 candle-power, besides a number of smaller lamps, was exhibited in the Newcastle Exhibition, 1888, suspended by three wires. The exhaust-pipe was of India-rubber, and the steam-pipe was provided with a flexible joint, so that the machine could be shaken about while running.

Multipolar Machines.—As the E. M. F. generated in dynamo-electric machines is dependent upon the rate of change of the cutting of the lines of force, the speed of the machine can evidently be reduced by increasing the number of poles presented to the armature. Modern electrical engineering is tending strongly to the adoption of multipolar machines, as they allow of more ready direct connection with the driving-engines.

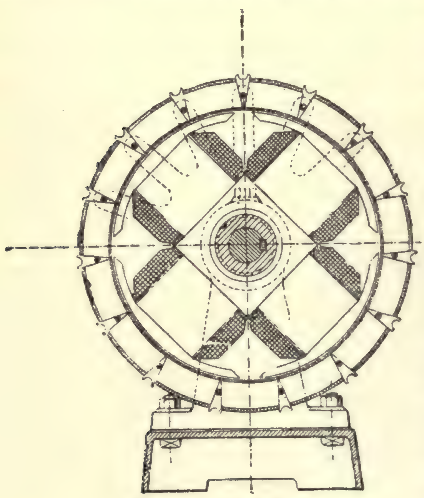


Fig. 67.—Siemens ring-dynamo.

The full-page illustration shows the latest type of *Edison Multipolar Constant Potential Generator*, direct connected to triple-expansion engines, one at each end of the driving-shaft. In this type, it will be noted, the armature rotates within a field-magnet having 10 poles. The frame of the field-magnet consists of but a single casting, and a very ingenious method has been designed by Mr. Edison for winding on the magnetizing coils. The Gramme ring type of winding is employed, but, instead of using coils of a number of convolutions connected to each segment of the commutator, in this type of machine each convolution is connected directly with the commutator-bar. For this purpose bare copper strips of U-shape are slipped over one side of the core, insulated from one another, and each succeeding U-shaped bar of this character is connected direct by a commutator-bar. The brushes bear upon the commutator in a vertical plane. This construction with bare conductors is permissible on account of the very small difference of potential, 1¼ volt existing between each bar. The number of bars employed in this type of machine is 944, and hence an equal number of commutator-bars is employed. Each bar is therefore equivalent to a coil of the usual type of Gramme winding, but the absence of contiguous layers entirely avoids self-induction, and hence sparking, the machine operating without the slightest indication of such a disturbance. Eight brushes are employed, which can be shifted simultaneously by means of the hand-wheel shown, and which can also be lifted at once from the surface of the commutator. The resistance of the

armature is ·006 ohm, and that of the field 8·45. Each dynamo is designed for 150 volts pressure and a capacity of 666 ampères. The design has been so well worked out that a variation of three quarters of the load can be made without requiring the slightest change in the position of the brushes.

The Siemens Multipolar Dynamo.—Figs. 67 and 68 show the Siemens ring-dynamo. In this machine the armature completely surrounds the fixed poles; hence, there is practically no waste of lines, and the close proximity of the magnet-cores near the axis insures a much shorter magnetic circuit than is obtained in a dynamo of the usual type. Practical experience has shown that the radial depth of the ring should be very small, that only one layer of wire should be wound on the armature, and that the commutator must contain a very large number of sections. The armature of the machine illustrated is 25 in. internal diameter, 8 in. long, and the total weight of the machine is 1 ton 4 cwt. At 350 revolutions per min. the output was found to be 16 kilo-watts, and at 480 revolutions it rose to 25 kilo-watts. Assuming about 20 kilo-watts as a safe load for continuous working, the weight of this machine is less by one third than that of the usual type made by Messrs. Siemens & Halske. In addition to this saving of weight, the machine has the advantage of being easily repaired, since the armature is outside, and can be slipped off the shaft *in situ* with-

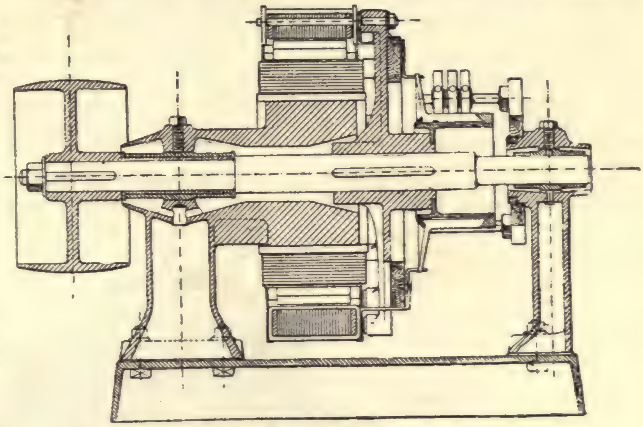


FIG. 68.—Siemens ring-dynamo.

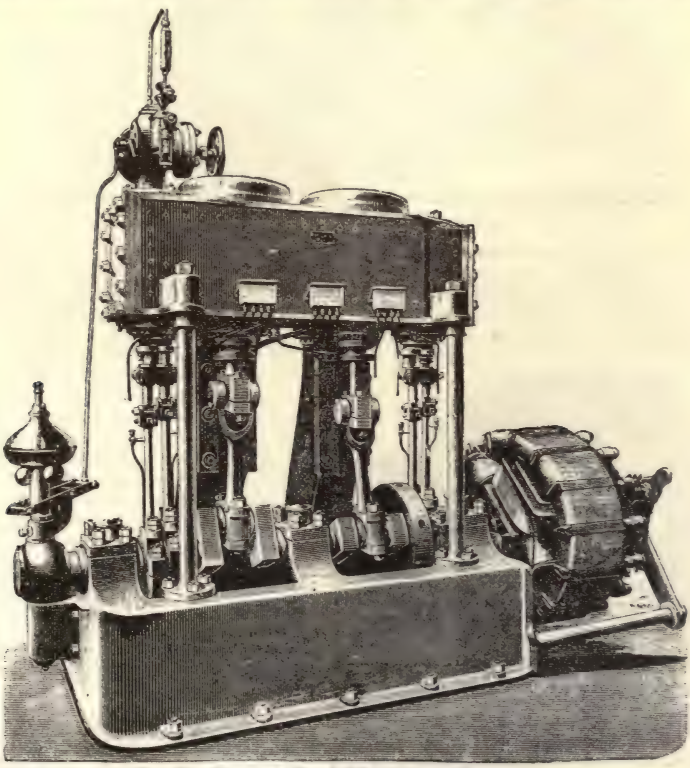


FIG. 69.—Siemens direct-driven steam-dynamo.

out any danger of the wires chafing against the field-magnets. After several of these machines had been made, Messrs. Siemens & Halske proposed to utilize the design for direct-driven steam-dynamos. It is evident that a machine with stationary field and overhanging external armature is not suitable for small sizes, and that its greatest advantage and power of competing with existing designs will be in such cases where, on account of the motor, the speed is limited. Fig. 69 shows the arrangement adopted in connection with a pair of open, direct-acting steam-engines. The field-magnets are attached to the end of the engine bed-plate, and the crank-shaft is prolonged so as to carry the overhanging armature. Outside the armature there is no bearing, but only the attachment for the brushes, which is secured by means of two columns, also fixed to the engine bed-plate. Messrs. Siemens & Halske have built several sizes of this dynamo, among which are four large machines for the installation at the railway station in Frankfort-on-theMain. Each of these machines is intended for an output of 75 kilo-watts, at a speed of 150 revolutions per min. Large dynamos built on this principle are also in operation at the Berlin electric-light station, working up to 1,500 horse-power.

Fig. 70 shows a view of a 250 horse-power Westinghouse electric-railway generator. There are four pole-pieces, and over each one is slipped a metal bobbin, which is secured in place by

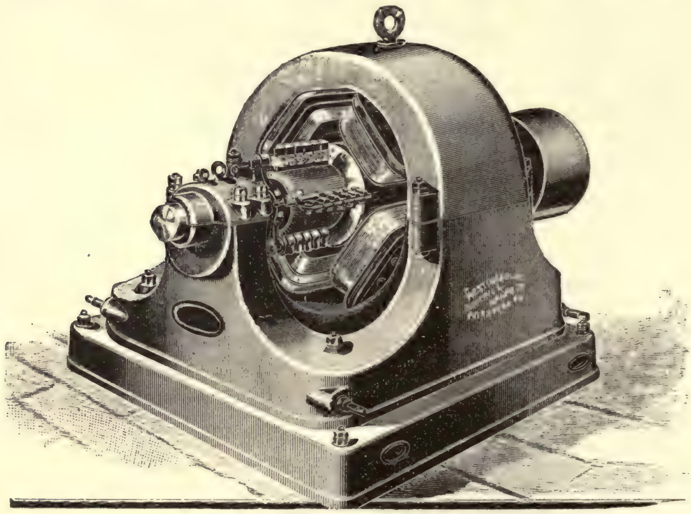


FIG. 70.—Westinghouse generator.

bolts. These bobbins carry the shunt and series coils, which are put on side by side and do not overlap. The pole-pieces are laminated, being built up of thin sheet-iron plates cast into the cylindrical yoke. The bearings and this cylindrical yoke part along a horizontal plane through the armature-shaft, thus giving ready access to the field-coils and armature. Each brush is held in an independent holder, so that any one can be raised from the commutator without disturbing the others; and each brush has its own spring, which permits of perfect adjustment. The diametrically opposite brushes are of the same polarity, and are connected to the same terminal of the dynamo. The core of the armature is built up of a large number of thin, soft-iron disks, which are forced together under great pressure, and rigidly fastened to the shaft. This iron core, after having been completely covered with special insulating material, forms the foundation on which the wires of the armature are laid. The Westinghouse 500 horse-power railway-generator is designed on lines similar to the machine just described, but with six poles.

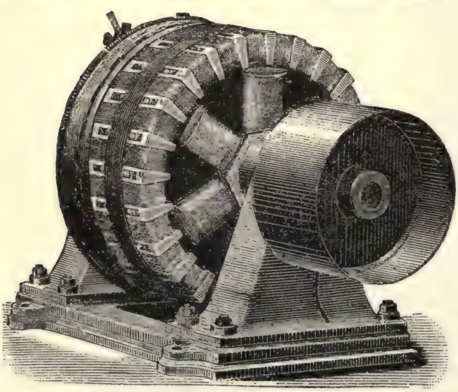


FIG. 71.—Ganz multipolar dynamo.

Ganz & Co.'s Multipolar Continuous-Current Dynamo.—In order to construct a machine which should have a large output with a comparatively small weight of material, Messrs. Ganz & Co., of Buda-Pesth, have designed the machine shown in the accompanying illustration (Fig. 71). As will be seen, the machine consists of six fixed electro-magnets, which are cast in one piece with the journal-bearing, while the ring, supported on one side only, rotates over and around the field-mag-

nets. The armature, which is destined for a 6-pole machine, is wound so that one sixth of the number of coils will generate the necessary difference of potential of 1,500 volts. These six sections are then joined in parallel in order to obtain a current of 35 ampères. Each of these six sections consists of 56 coils, having 12 convolutions each, so that the commutator has $56 \times 6 = 336$ sectors or bars. The sixth corresponding commutator-bars are all jointly connected, so that the current is taken off by a single pair of brushes instead of six.

The most recent form of this machine when running at 1,000 revolutions per min. generates a current of 35 ampères at 1,500 volts; and the following data of its construction are of interest:

Resistance of armature	0·97 ohm.
" " magnets	0·28 "
Weight of copper on armature	23·5 kilogrammes.
" " " " "	58·5 "

According to the above data, the total output of the machine is 52,500 watts; this gives 640 watts per kilogramme (about 290 watts per lb.) of copper, the total weight of the machine being 685 kilogrammes. The electrical efficiency of the machine is 97·2 per cent, according to the above data, which is an unusually high figure, and its commercial efficiency is also high. The machine was specially designed for the transmission of power where small weight and large capacity are desired.

The Wenström Dynamo.—This machine, in its improved form, is shown in perspective in Fig. 72, and in longitudinal section in Fig. 73. It is a 4-pole machine, but so constructed

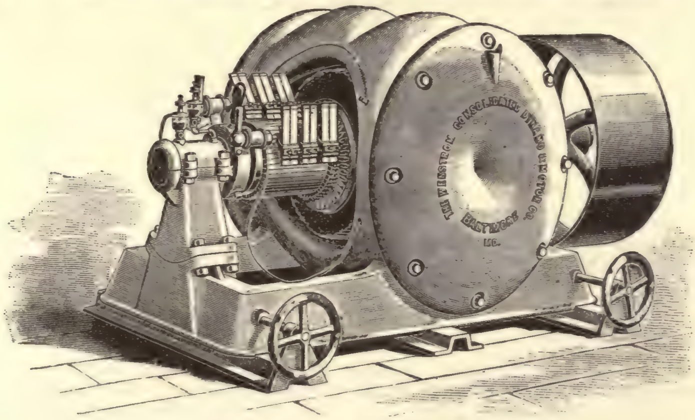


Fig. 72.—Wenström dynamo.

that two exciting coils are sufficient, the N-poles being energized direct, and the two consequent S-poles by induction. The brushes are placed at an angle of 90° on the commutator.

Usually the space between the magnet-poles and core of the armature must be sufficient not only for the safe revolving of the armature at a high rate of speed, but also for the con-

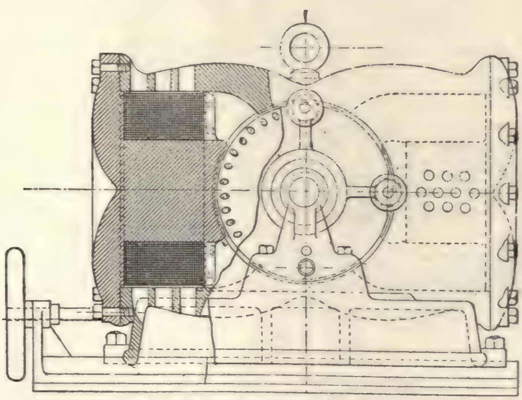


Fig. 73.—Wenström dynamo—section.

ductors in which the currents are induced. This gap introduces a very high magnetic resistance in the circuit for the magnetic induction. To avoid this, therefore, the conductors

are buried in grooves or holes (Fig. 74). The distance between the poles and the core is thus limited to the small gap required for the safe revolving of the armature. The magnetic resistance and the magnetic circuit are by this means reduced in a high degree, and consequently the magnetizing power necessary for creating the required magnetism in the armature is also decreased.

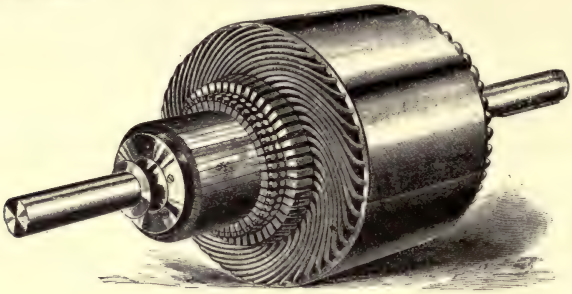


FIG. 74.—Multipolar armature.

A test made by Dr. Louis Duncan, Dr. G. A. Liebig, and Mr. W. F. Hasson, of Johns Hopkins University, on a 400-ampère 110-volt dynamo of this type, gave the following results. The machine was built for 400 revolutions per min., and weighed 7,100 lbs.; in the test it was run at 330 revolutions:

Current, ampères.	E. M. F., volts.	Horse-power.	Dynamometer, horse-power.	Loss.	Losses, friction reversals.	C^2 R.	Efficiency, per cent.
134·8	114	20·6	24·97	4·4	4·4	0·17	82·5
194·1	115·6	30·1	35·3	5·2	4·5	0·52	85·2
371·6	98·3	49	54·5	5·5	3·5	1·30	89·9
400	110	58·9	64·7	5·8	4·1	1·50	91

The Bradley Multipolar Dynamo.—The armature of this machine has the conductors wound upon it in one continuous course, so that the distance between each two successive induced portions of the conductors is greater or less than that between the poles of the field-magnets, according to the formula:

$$D = d - \frac{n}{p}; \text{ or, } D = \frac{n}{p} - d.$$

The induced current flows from one brush to the other through the whole system of conductors in such manner that, however simple or complex the system of conductors may be, the average value of the distance d between every two induced parts which follow next to one another always conforms to the condition,

$$d = \frac{u}{p}\left(1 \pm \frac{1}{n}\right),$$

where u = average circumference of armature, n = number of segments of the collector, p = any number of field-magnets not less than four.

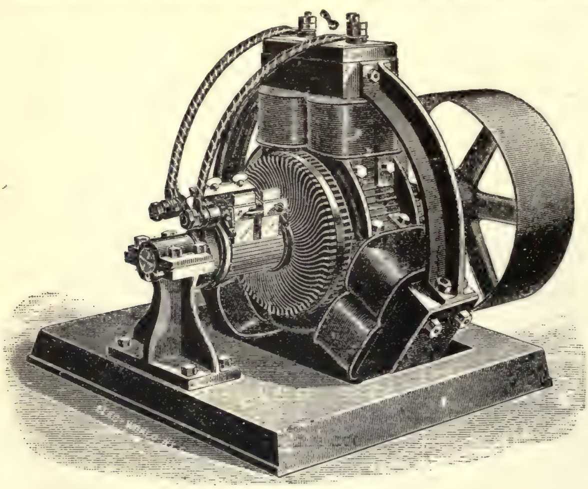


FIG. 75.—Bradley multipolar dynamo.

In the machine shown in the engraving (Fig. 75) there are 74 slots cut in the armature $1\frac{1}{16}$ in. deep, $\frac{192}{1000}$ in. wide at the circumference, and $\frac{107}{1000}$ in. wide at the bottom. This leaves the iron the same thickness between the slots at the bottom as at the top, the aim being in these machines to have the magnetic circuit the same in cross-section in all its parts. The sectional area of the yokes, cores of the magnets, and the sum of the cross-sections of the bodies of iron between the slots which are under the pole-pieces at any one time, are approximately equal. Two bars are placed in each slot, the top one being longer than the bottom one, so as to project beyond it at each end to join the connectors. The top bar is $\frac{420}{1000}$ in. wide and the bottom $\frac{680}{1000}$ in., so each has the same sectional area.

The connectors (Fig. 76) are clamped firmly to the side of the bar and soldered, and then the clamp is removed, the surfaces soldered being much larger than the sectional area of the bars. Mica insulation is used between and at the side of the bars. The slot is $\frac{1}{16}$ in. deeper than the bars, so that it leaves a space below the same to insulate them from the iron. There are 74 bars in the commutator, each connector on one end of the armature leading to a bar. The brushes may be placed 60° or 180° apart. On the machine shown, they have been placed 60° apart, but, all things considered, 180° is preferable.

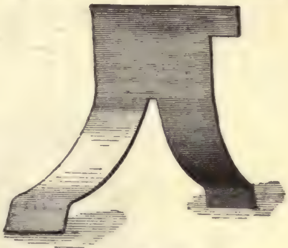


FIG. 76.—Connectors.

The iron of the armature runs in such close proximity to the field-magnets (the clearance necessary for rotation being the only gap in the magnetic circuit) that the expenditure of energy on the field-magnets is very small, being less than $1\frac{6}{10}$ per cent of the total when the machine is fully loaded. This must be conceded to be a remarkably good result when the slow speed of the machine is taken into consideration.

The following table gives the results of a test of the machine illustrated, made by Dr. W. E. Geyer and D. G. Jacobus, M. E., at the Stevens Institute of Technology:

NUMBER OF TEST.	Speed of armature, revolutions per minute.	Volts.	Ampères.	Efficiency, per cent.
1	556·6	50	134·40	84·1
2	547·2	50·1	136·94	84·5
3	546·3	51·5	138·59	83·9
4	559·2	45	253·82	86·3
5	581·4	51	271·34	86

The base of the machine is 31 × 31 in., and it stands 26 in. high. The diameter of the armature is $12\frac{3}{4}$ in., and the length of its core 6 in. The following table gives the weights of iron and copper employed in its construction:

	Lbs	Lbs
Field—Iron, soft Norway	340	
" " cast	28	
" Brass	23·5	
	——	391·5
" Wire		108·0
" Bed, standards, bolts, etc		235·3
" Brush-holder, brass		10·7
Armature—Iron (sheet)	153	
" " cast end-plates	14·2	
" Steel shaft	36	
	——	203·2
Copper in armature	59	
" " commutator	13	
	——	72
Brass commutator-core		5
Total weight of machine		1,025·7

The Desrozier Multipolar-Disk Dynamo is illustrated in Fig. 79. The winding, which characterizes the Desrozier machine, is shown in Figs. 77 and 78, and is arranged for an armature divided into 52 sections. By this arrangement the space between the poles is fully utilized; each section has a well-defined position, and an armature so constructed affords every facility for repairs and for inspection while at work. By a modification of the collector and its connections, M. Desrozier has avoided an increase in the number of coils. He connects each triple coil not to a single bar but to three, 120° apart in the case of a 6-pole machine. The brushes, in lieu of uniting the ends of a single coil, only unite the ends of a single coil, and each single coil is short-circuited several times under each brush at every revolution. This method of connecting up will be understood on examining Figs. 77 and 78. The connections would be inextricable if the inventor had not made use of the properties of the involute. The wires are therefore all united

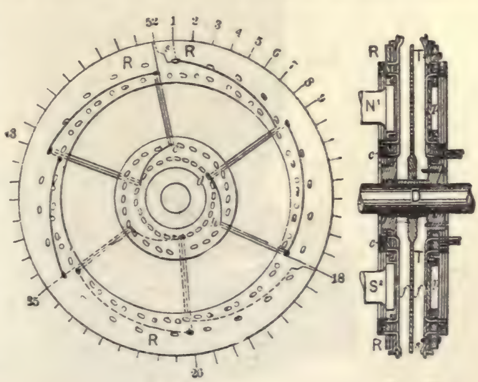


FIG. 77. FIG. 78.

FIGS. 77–78.—Plan of winding.

with a special piece of apparatus, called the analyzer, and which is placed beween the disk and the collector. The three wires of each coil come from the center of the armature to an insulated disk: wire 1 passes on straight to the collector-bar; wire 1′ is wound in involute on one side of the disk, and runs thus to bar 1′; wire 1″ passes through the disk, is wound backward through 120°, and terminates at bar 1″. In this way all the wires are arranged side by side on either face of the analyzer, and no mistakes are to be feared. It is not necessary to enlarge further upon the practical advantages of these arrangements, allowing as they do very satisfactory working of the collector. It would be impossible otherwise to stop sparking without increasing the number of coils, or increasing the distance between the successive poles. Several Desrozier machines have been built by the firm of Bréguet, and placed on board the French ironclad Formidable. These machines weigh 2,640 lbs. each, run at 350 revolutions, and have an output of 175 ampères at 70 volts; their electrical efficiency is 82 per cent, and their commercial efficiency is 79 per cent. It varies very little with the work. According to the inventor, it is very probable that the efficiency of the Desrozier dynamo would be considerably higher if constructed to meet ordinary commercial requirements.

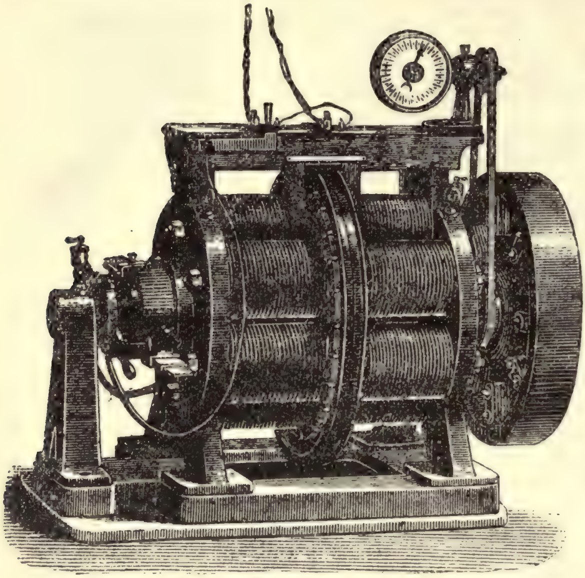


FIG. 79. Desrozier dynamo.

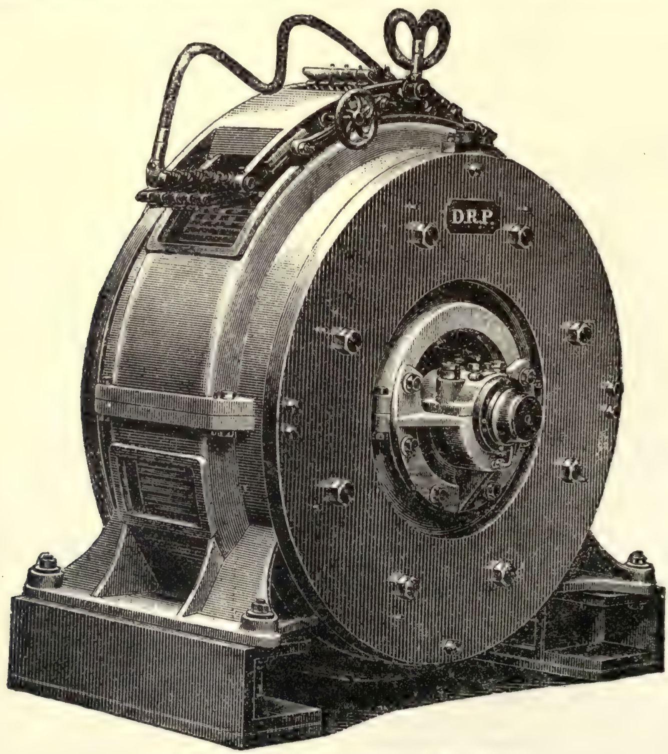


FIG. 80.—Fritsche and Pischon dynamo.

The Fritsche and Pischon Dynamo is illustrated in Fig. 80, and is known as the "wheel" dynamo, owing to the peculiar shape of the armature.

The armature-bars consist of specially shaped punchings of sheet-iron and sheet-copper, which are riveted together. They are long and thin, and are illustrated in Fig. 80A. The punchings are soldered and riveted at the top and bottom to the specially shaped brass castings *A* and *B*. Copper bars are screwed on to the castings *A*, which are then turned off on the circumference and serve as commutator-blocks. As the armature-loops are connected in series, two sets of brushes only are required. The lower castings *B* are mortised on both sides, and by this means the whole armature is clamped together with strong cast-iron hubs, *C*, which have brass end-rings, *D*, in order to magnetically insulate the hub from the armature-bars. Pressed-board insulation, *E*, is used between the ring *D* and the armature-spokes. The largest machine that is being built at present is designed for 180 K. W., and the following data regarding it will be interesting:

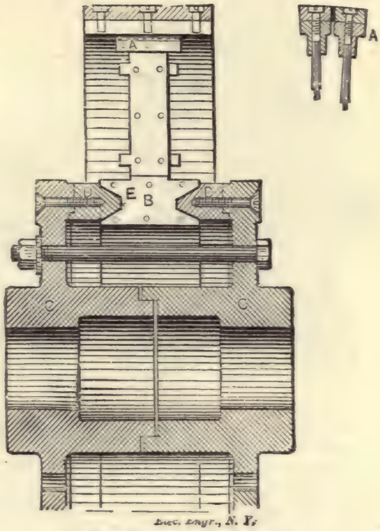


Fig. 80A.—Armature-bar.

Output................	150 volts 1,200 ampères.
Speed..............	100 revolutions per minute.
Weight of armature................	8,800 lbs.
Weight of copper on fields.........	1,080 lbs.
Total weight of machine complete..	20,240 lbs.
Loss in magnet and armature conductors......................	3·5 per cent.

The following is a table of sizes and general data of the standard Fritsche machines:

	Output in kilowatts.	Volts.	Ampères.	Speed.	Number of poles.	Weight complete in lbs.
Exhibition machine...........	32	160	200	400	4	5,280
	48	160	300	140	8	8,800
	180	150	1,200	100	12	20,240

Unipolar Dynamos.—These machines are constructed so that the conductor in which the currents are generated (armature) effects a continuous increase in the number of magnetic lines cut, by arranging one part of the conductor to slide on or around the magnet. Sturgeon's wheel and Faraday's disk are types of these machines. Messrs. Siemens & Halske have constructed a unipolar dynamo for electro-deposition (Fig. 81). In this remarkable dynamo there are two cylinders of copper, both slit longitudinally to obviate eddy-currents, each of which rotates round one pole of a U-shaped electro-magnet. A second electro-magnet, placed between the rotating cylinders, has protruding pole-pieces of arching form, which embrace the cylinders above and below. Each cylinder, therefore, rotates between an internal and an external pole of opposite polarity, and consequently cuts the lines of force continuously by sliding upon the internal pole. The currents from this machine are of very great strength, but of only a few volts of electromotive force. To keep down the resistance, many collecting-brushes press on each end of each cylinder. This dynamo has been used at Oker for electroplating.

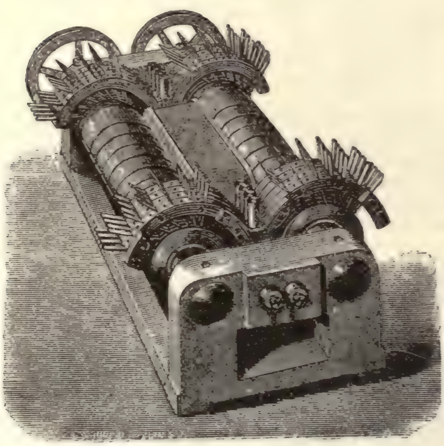


Fig. 81.—Unipolar dynamo.

The Forbes Dynamo has also attracted considerable attention, on account of its enormous current output for a given weight. Originally Prof. Forbes began by employing an iron disk which rotated between two cheeks of opposite polarity, the current being drawn from its periphery. He then doubled the parts. The next stage was to unite the two disks into one common cylinder, as shown at *A* in Fig. 82. Here the coils lying in their cases are shown in section, the dotted lines indicating the direction of the lines of magnetic force induced in the iron. These are practically closed on themselves, so that there is no external field at all. For this reason the inventor prefers to call this type of dynamo "non-polar." A rubbing contact, for which purpose Prof. Forbes at one time used carbon "brushes," and at another a number

of springy strips of metal-foil, is maintained at the two extremities of the periphery. One of the earlier forms of machine, with a single disk 18 in. in diameter, was stated to give 3,117 ampères at a potential of 5·8 volts when running at 1,500 revolutions per min. One of the later machines, in which the "armature" is a cylinder of iron 9 in. in diameter and 8 in. long, is designed to give, at 1,000 revolutions per min., a current of 10,000 ampères at a potential of 1 volt. The electromotive force of such machines increases as the square of the diameter. The theory of the unipolar disk machine has been given by Sir W. Thomson, who has shown that such a machine is not self-exciting except above a certain critical speed, dependent on the resistance of the circuit.

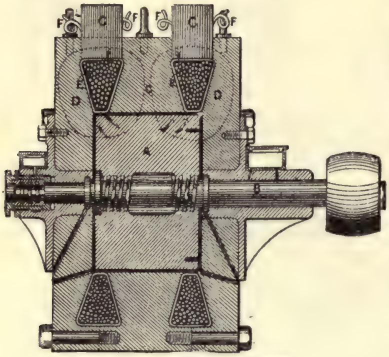


Fig. 82.—Forbes dynamo.

Alternating-Current Machines.—In general the methods of mechanical construction adopted in these machines do not differ materially from those of the continuous machine. In the alternating machine, however, the use of the commutator becomes superfluous, the current generated in the armature being led merely to a pair of rings attached to the shaft, and upon which the brushes bear. Special precautions, however, are necessary to avoid piercing of the insulation on the armatures of such machines, and for that purpose mica is now almost exclusively employed. In these machines, also, thorough lamination is imperative.

According to Kapp, if we calculate out the E. M. F. of an alternate-current machine by applying to it the now well-known formulæ for continuous-current dynamos, there will then be a certain numerical coefficient by which the E. M. F. thus found must be multiplied in order to obtain the actual mean alternating E. M. F. of the machine. The value of this coefficient, K, depends chiefly upon the relative width of the field-magnet poles and space between, and also upon the amount of the surface of the armature which is covered with wire. The following table gives the value of K for different cases:

1. Width of poles equal to pitch, toothed armature and winding concentrated in the recesses.............. $K = 2·000$
2. Width of poles equal to pitch, smooth armature and winding spread over the whole surface.............. $K = 1·160$
3. Width of poles equal to pitch, smooth armature and winding covering only one half the surface.............. $K = 1·635$
4. Width of poles equal to half the pitch, smooth armature and winding spread over the whole surface.............. $K = 1·635$
5. Width of poles equal to half the pitch, smooth armature and winding covering only one half the surface.............. $K = 2·300$
6. Width of poles equal to one third the pitch, smooth armature and winding covering only one third of the surface.............. $K = 2·830$

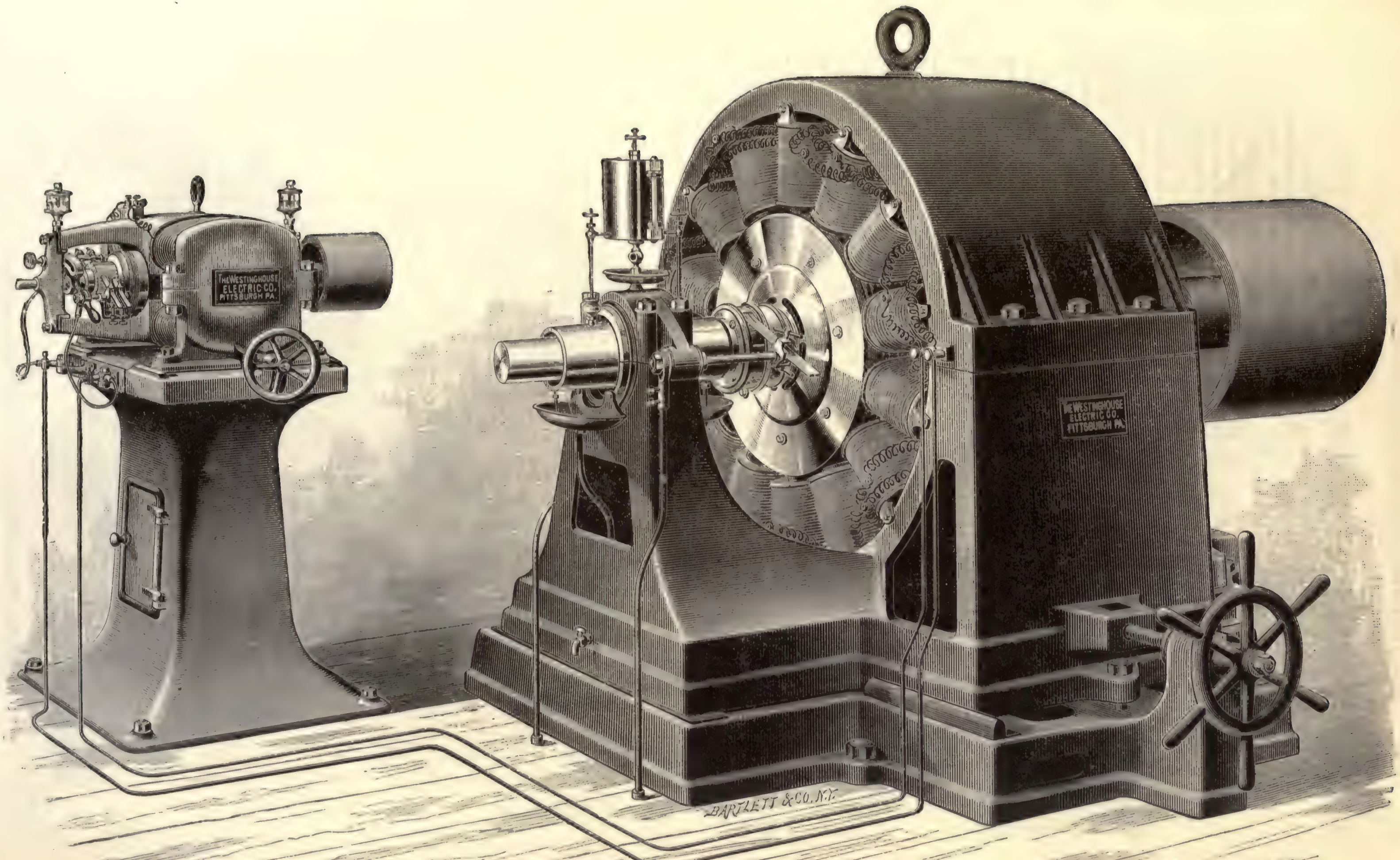
According to the ordinary sine formula, the coefficient is $K = 2·220$, and this agrees fairly well with case 5, which is the one most frequently met with in actual practice.

The Westinghouse Alternating-Current Dynamo (Incandescent).—The machine at present very largely employed in the United States for incandescent lighting on the alternating system is that of the Westinghouse Electric Co., shown in perspective, with its exciter, in Fig. 83. The Westinghouse Co. makes five sizes of dynamo, of which the following particulars are of interest:

Dynamo number	I.	II.	III.
E. M. F.	1,050	1,050	1,050
Current	35	65	130
Resistance (armature) at 30° C.	·76	·37	·15
" (fields) at 30° C.	14·5	7	3·6
Weight of wire in armature	17	30	60
" " fields	420	.....	.....
Total weight	4,800	9,000	.....
Number of lights	650	1,300	2,600

The No. III has an armature about 2 ft. in diameter and 2 ft. long. It has 16 poles, and runs at 1,000 revolutions per min. The armature plates have each six large holes for ventilation and lightness. The weight of armature is 2,000 lbs. The insulation is mica and copal varnish, which is found to be much superior to shellac or any other material tried.

Fig. 84 is a side view and Fig. 85 is an end view, from which the construction will be easily understood. The field-magnets, bolted to the external frame of the machine, form a circle, radiating inward toward the armature, which is mounted in the center on standards rising from the base. They are of elliptical form, the longer axis of a cross-section of each core being parallel to the armature-shaft, as shown at f and $g\,g$, Fig. 84, the edges of the


THE WESTINGHOUSE
ELECTRIC CO.
PITTSBURGH PA.
THE WESTINGHOUSE
ELECTRIC CO.
PITTSBURGH PA.
BARTLETT & CO. N.Y.

cores being shown at $f\,f$, Fig. 86. The winding of each magnet is opposite to that of the adjacent one, so as to produce north and south polarity. The coils are slipped on the cores after being wound. The armature-core is composed of sheet-iron disks, insulated by paper, and having tubular openings for ventilation parallel to the axis; a great number of these being laid together, the openings registering to form the tubes, and then bolted together by end-plates, as shown. The winding differs from that of the Gramme armature in having no interior wire. The coils consist of single layers of wires wound on the external surface of the core and looped around projections $m^1\,m^2$ at the ends, attached to non-magnetic rings o^1, so that the planes of the coils are at right angles to the radii of the armature, and there are no crossing wires at the ends, as in the Siemens, nor wire in the interior of the ring, as in the Gramme; the ends being exposed for ventilation through the tubular openings in the core. Adjacent coils being wound oppositely, as in the field-magnets, as shown in Fig. 87, generate alternating, opposite currents. The coils are insulated from the core with mica, and also covered externally with the same material, and firmly bound with the bands $j^1\,j^1$. The space between the armature and the field-magnets being only $\frac{3}{16}$ in., and there being only a single layer of wire on the armature surface, both the coils and the core are in close proximity to the field-magnets, and hence the mag-

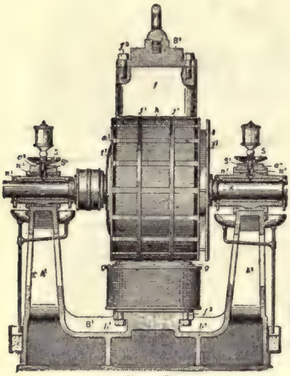


FIG. 84.

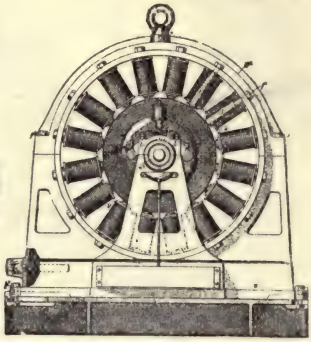


FIG. 85.

FIG. 86.

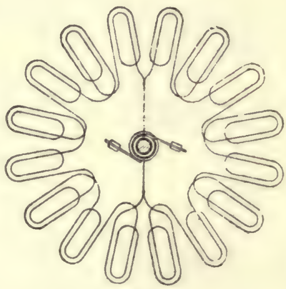


FIG. 87.

FIGS. 84-87.—Westinghouse dynamo—details.

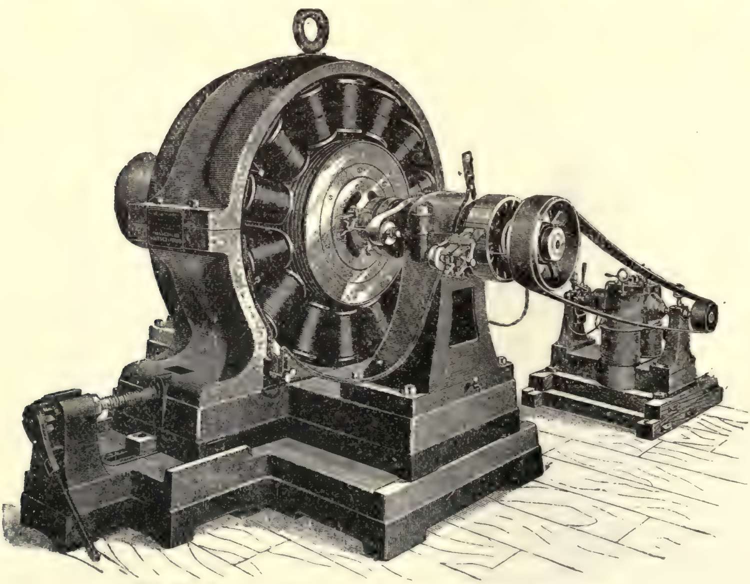


FIG. 88.—Thomson-Houston alternating current dynamo.

netic and electric reciprocal actions are at the maximum, and there is no dead or partially inactive wire in the interior; all the wire, except a very small percentage on the ends, being exposed to the full action of the magnetic field. A Stanley direct-current, shunt-wound dynamo is used as an exciter.

The Alternating-Current Machine of the Thomson-Houston Electric Co., designed by Prof. Elihu Thomson, is illustrated in Fig. 88. Its distinguishing feature is its self-regulating property, by which a constant potential is maintained at all loads. This is accomplished by an arrangement of the coils on the field-magnets of the dynamo, called a "composite field," in which practically the same methods are employed as in the direct-current incandescent dynamo of Prof. Thomson (see above). As shown in the diagram (Fig. 89), a part of the magnetic field is maintained by means of current from a separate exciting dynamo. If the load upon the outside circuit is increased, it is necessary to increase the magnetism of the field in order that the machine may, in turn, supply the increased demand in the circuit, and the lights remain steady. This is usually accomplished by varying the current on the field-magnets by a rheostat or variable resistance operated by hand. In the dynamo under consideration, however, the same result is obtained entirely automatically by passing the greater portion of the main current through the field-magnets, thus energizing the machine in exact accordance with the demands made upon it. As an alternating current is not suitable for magnetizing the fields, it is necessary to change the character of the current produced in the armature to a direct current before passing it through the special winding on the field, and this is done by a commutator at the end of the shaft. By this regulation the attention required at the dynamo is reduced to a minimum, while at the same time the efficiency of the machine is increased, and any number of lamps from one to the full capacity may be thrown on or off without in any way affecting the steadiness and brilliancy of those remaining. To allow for a predetermined percentage of loss in the wiring, it is necessary, as the load is increased, that there should be a definite amount of increase in potential, which is accomplished by placing around the field-winding for the main current a resistance which shunts that portion of current not required for regulation.

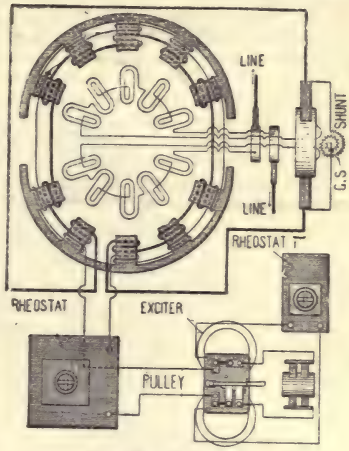


FIG. 89.—Connections.

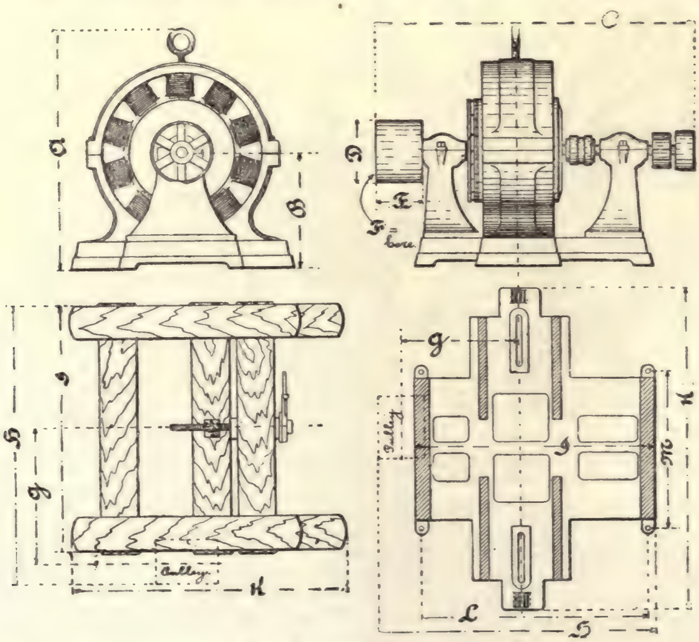


FIG. 90.—Detail diagram.

The coils for the field-magnets are wound on spools which are slipped over the castings and fastened firmly in position. These being well protected, the liability of mechanical injury is reduced to a minimum. In case it is necessary to replace a coil, or to remove the

armature, the upper half of the field-casting can be readily removed, leaving the parts easily accessible. For the purpose of energizing the field-magnets the dynamos are furnished with small exciting dynamos of the direct-current type. It has been found desirable in some special cases to make the smaller sizes of alternating-current dynamos self-exciting, and to this end the armatures are wound with an extra or special coil for furnishing current to energize the fields. The exciter is usually placed as shown in Fig. 88, behind the alternating dynamo, driven by a belt from a small pulley attached to the armature-shaft. One exciter is usually employed with each alternating-current dynamo, but when several dynamos are operated in the same station it is often found more convenient to employ exciters, any one of which is of sufficient capacity for all the machines. By this arrangement an accident to one exciter need not affect the general service.

The accompanying diagram (Fig. 90) and table give the various dimensions, weights, capacity, etc., of these machines:

CLASS.	A, 18.	A, 35.	A, 70.	CLASS.	A, 18.	A, 35.	A, 70.
Net weight	*2,100	*3,570	*8,270	C	48¼	67	85
Weight of base	150	615	1,245	D	13	13	18
Material of base	Wood.	Iron.	Iron.	E	6	10	13
Speed	1,500	1,500	1,070	F	1 15/16	2¾	3 7/16
Lights	300	650	1,300	G	24⅛	23¾	33¾
Horse-power to drive	30	65	130	H	43¼	55¾	73¼
Watts	18,000	35,000	70,000	I	42	47	61⅛
Poles	10	10	14	K	48	67	86
A	44	47¼	61¼	L	..	†41⅝	†58
B	23¼	21¾	29⅛	M	..	†31¼	†39¼

Ganz & Co.'s Alternating-Current Dynamo.—A type of alternating-current dynamo very largely employed in Europe is that built by Messrs. Ganz & Co., of Buda-Pesth, Hungary. In its early form the Ganz alternator had a star-shaped field-magnet of non-laminated iron revolving within a cylindrical armature, the core of which was composed of thin ring-shaped iron plates held in a frame. The armature-coils were flat bobbins laid upon the inner surface of the armature-core side by side, with insulated filling-in pieces interposed. The magnetic resistance of the interpolar spaces was in this arrangement necessarily high, and in the later machines this difficulty has been overcome by employing an armature-core with a series of internal Pacinotti projections. These projections form the cores of the armature-bobbins, and to avoid the heating of the pole-pieces, the field-magnets are now built up of U-shaped iron plates *F*, as shown in Fig. 91. These plates are laid upon each other, and arranged round the spindle so as to form a star, alternate layers being arranged to break joint, as shown by the dotted lines in the illustration. The plates are fastened together by insulated bolts *B*, and the existing coils are wound upon separate formers, slipped over the magnet-cores, and held in position by bobbin-holders and screws strong enough to resist the action of centrifugal force. The armature-core, which formerly was continuous, is in the new machines subdivided into a number of T-shaped sections, the central stem of the T forming the Pacinotti projection *A*, being very short, and of equal width and length with the magnet. These sections are so arranged that each with its armature-bobbin can be removed without disturbing the rest of the machine. The illustration also shows the construction of the armature-sections, and the manner of supporting them. The frame of the machine consists of two ring-shaped castings held together by strong bolts, and, in addition, there are iron traversers to which the segments are bolted. In the figure, the section at I is taken close to one of the cast-iron rings, showing the internal flange to which the traversers are bolted. The section at II is taken at some intermediate point, showing the traversers and the plates of the armature-core; and the series at III is taken at another intermediate point, showing the method by which the armature-core is

FIG. 91.—Ganz & Co.'s alternating-current dynamo.

* Without base. † Approximate.

bolted to the traversers. The armature-plates are held together by ribbed bronze plates, which also serve to hold the armature-coil in its place. In larger armatures bronze plates are also inserted at intermediate points, and they serve for the attachment of the armature-section to the traversers by means of insulated bolts and nuts, as shown at III.

Fig. 92 shows a complete machine intended for an output of 80 kilowatts. In this machine there are 14 poles and 14 armature-sections, which can be coupled to give a pressure of either 2,000 or 4,000 volts with a current of respectively 20 or 40 ampères. The speed of the machine is 360 revolutions per min., giving 5,040 reversals, or a frequency of 42. The total weight of the iron core, both in field-magnets and armatures, is 1 ton 7 cwt., and the total weight of copper is 930 lbs. The resistance of the armature is 1·038 ohms for a 2,000-volt machine, giving a loss of 2·08 per cent by ohmic resistance in the armature circuit. The resistance of the field-magnet circuit is 3·24 ohms, and a current of 28·7 ampères is required at full output, entailing a loss of 3·33 per cent for excitation. Some experiments were made with this machine to ascertain the various losses. When driven in a non-excited field by a belt at the normal speed, 4·07 horse-power was consumed in journal friction and windage. The field-magnets were then excited so as to produce a terminal pressure of 2,000 volts, but no current was allowed to flow through the armature. Under these conditions the power absorbed was 9·81 horse-power, showing that hysteresis and Foucault currents absorbed 5·74 horse-power. The total commercial efficiency, including the power required to excite the machine, is at full output 87 per cent; and this figure is somewhat increased when the machine is direct driven by a steam-engine. In order to facilitate the cleaning of the armature-coils, Messrs. Ganz & Co. have from the very first arranged the frame of the armature in such a way that it could be shifted longitudinally beyond the space occupied by the field-magnets, so as to expose the whole of the internal surface, and make it easily accessible, both for cleaning and for the renewal of a coil should it have been damaged. In the new type of machine, the armature itself is, however, kept fixed, and the magnet-wheel is arranged to slide longitudinally, for which purpose one of the standards is fitted similarly to the slide-rest of a lathe. In order to slide back the magnets, the pulley must be removed, and the standard on the opposite side can then be drawn back by means of a ratchet-bar, screw, and nut to its outermost position.

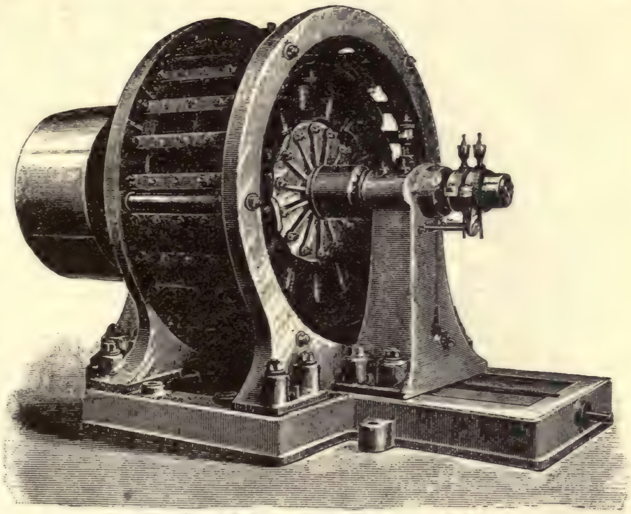


Fig. 92.—Ganz & Co.'s alternating-current dynamo.

The Ferranti Alternating Machine is shown in perspective in Fig. 93, and Fig. 94 shows the construction of the field-magnet frame. The machine illustrated is designed for an electrical output of 150 horse-power, and is therefore capable of feeding 3,000 10-candle-power 35-watt lamps. As will be seen, there are 20 magnets on each side of the armature, the distance between the pole-faces being $\frac{3}{4}$ in. Between the magnets the armature, which is $\frac{1}{2}$ in. wide and has a diameter of 4 ft., makes 400

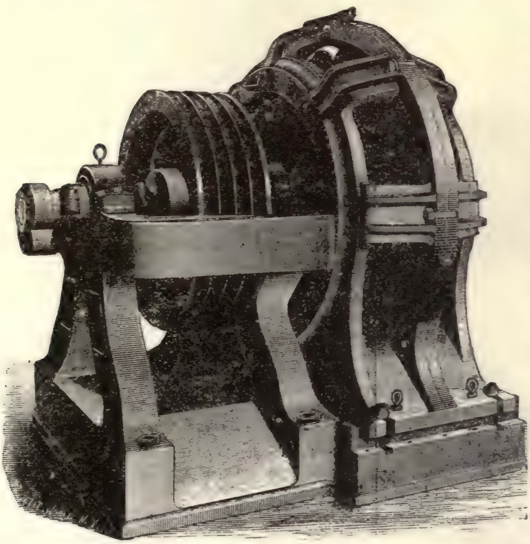


Fig. 93.—Ferranti alternating-current dynamo.

revolutions per min., and has a peripheral speed of 4,800 ft. per min. The diameter of the armature-shaft is 4½ in. It will be noted that the pulley is placed between two bearings and that the armature is overhung.

Machines of this type are now in course of construction (August, 1891) capable of furnishing current for 200,000 lamps. They will be installed at the Deptford station in London.

The following are a few of the details of the Ferranti-Deptford dynamos: The small machines are 12 ft. 6 in. high, 15 ft. over all; the large machines will be 45 ft. high over all, and will weigh 500 tons each. The number of alternations of current will be 4,000 complete cycles per min. (67 per second) in all machines. In the small machine there will be 48 poles, and the speed 168 revolutions per min. The large machines are to be coupled direct, and the speed is 60 revolutions per min. only, the peripheral speed being obtained by the largeness of their diameter. The coils of the dynamos are built up in the same manner as an ordinary dynamo's, each coil generating 125 volts. These are very strongly mounted mechanically, and most carefully insulated, the principle being to bury the conductors in the insulation. The insulation used is sulphur, specially treated, and is so hard that in one case where some metal was found to be mixed with the sulphur it took two days to chip out one coil. The sulphur eats partially into the cast iron and bronze, and makes a thorough joint. Besides this, the surface insulation is carefully arranged to be of porcelain throughout. The electrical efficiency of the armature is very great, two volts being obtained for every foot of copper.

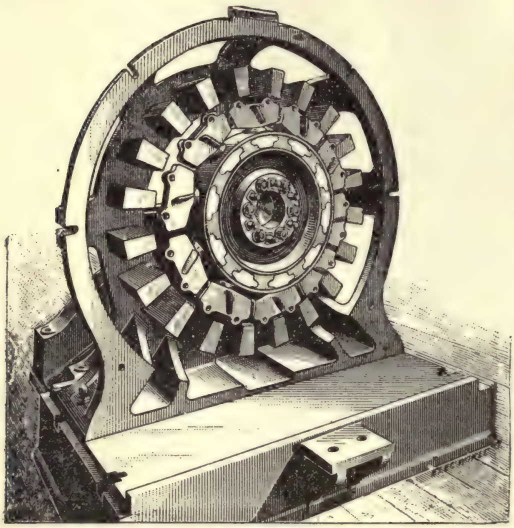


Fig. 94.—Ferranti dynamo.

The Mordey Alternating Dynamo.—This excellent machine was designed by Mr. William M. Mordey for the Brush Electrical Engineering Co. of London, and possesses a number of valuable characteristics. Fig. 95 shows the machine complete, and Fig. 96 the armature, which is stationary, and consists of a number of coils of narrow copper ribbon, wound on cores of non-conducting material. Each coil is bolted between two brackets, the ends of the conductors being brought out through porcelain insulators. The brackets are then bolted to a gun-metal supporting ring, being placed outside of the magnetic field so as to avoid loss from eddy-currents, which are still further reduced by the employment of German silver for the brackets and bolts. The gun-metal supporting ring, which is bolted to the bed-plate of the machine, is in two portions, being divided in a vertical diametrical line. These two parts, after having received the coils, are bolted together and to the bed-plate, the field-magnet being first placed in position. This design provides ample facilities for repairs, as it allows not only of single coils of the armature being quickly removed and replaced, but also renders it easy to take out one half or the whole of the armature.

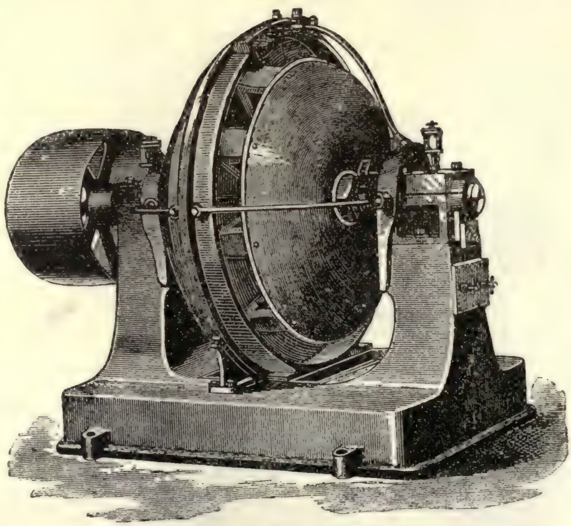


Fig. 95.—Mordey alternating dynamo.

The field-magnet, shown in Fig. 97, consists of a single electro-magnet, built up as follows: A short cylinder of iron, through the axis of which the shaft passes, forms the core of the magnet, and round this core is wound the exciting coil. Against each end of this cylinder is placed a cast-iron piece, of a form which will be best understood from Fig. 97. Each casting has a number of horns or arms which radiate from the shaft

and central part of the casting, and then bend over, forming nine pole-pieces on each side of the armature. These horns on one side, as will be seen, approach within a very short distance of those on the other side of the armature, and in this very narrow polar gap or slit the armature is held, the entire field-magnet revolving with the shaft on which it is mounted. The ends of the exciting coil are connected to "collector" rings on the shaft, which are shown to the right of the illustration. It will be observed that this form of field-magnet is very simple. A single exciting coil suffices for a machine of any size, speed, or number of alternations. Besides its peculiarity of form it differs from the usual arrangements in that it has poles of one sign only on each side of the armature; thus the magnetic leakage between adjacent poles on each side is absolutely *nil*. By revolving the field-magnet, instead of the more delicate armature, safety and steadiness of running are secured, the heavy magnet acting as an excellent fly-wheel, and effectually neutralizing any pulsation due to irregularity in the stroke of the engine.

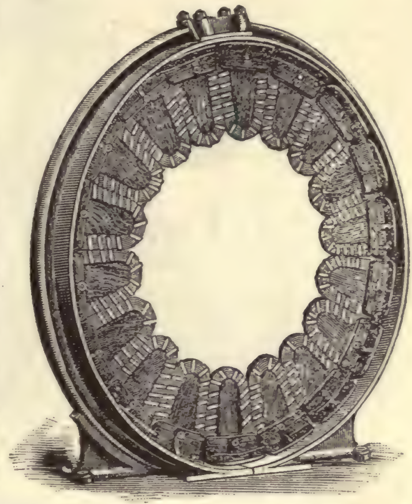


FIG. 96.—Mordey armature.

The machine is very nearly self-regulating in itself. It is therefore not considered necessary or desirable, except under special circumstances, to provide other than a simple hand-regulation at the dynamo for the purpose of controlling the potential difference. By the arrangement of the armature-coils it is easy to obtain various combinations if desired. This circumstance is made use of for simplifying the measurement of the potential. Instead of taking the reading across the terminals, which would necessitate the use of an electrometer, or a very high resistance voltmeter, an ordinary voltmeter, indicating to 100 or 150 volts, is placed across one of the coils, the machine being fitted with a special pair of voltmeter terminals for this purpose. The indication thus obtained, multiplied by the total number of armature-coils, gives the potential difference between the armature terminals. The voltmeter may, if desired, have its dial marked to directly indicate the total potential difference. It is said that this dynamo of 50 to 60 horse-power—the first of its type—was built directly from the first design, without recourse to any preliminary experiments. The machine illustrated has an output of 40,000 watts, at a potential of 2,000 volts, and a speed of 650 revolutions per min. In the latest type of this machine a separate exciter for the revolving field-magnets is employed, coupled directly to the same shaft.

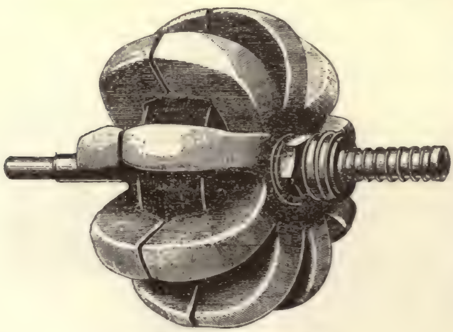


FIG. 97.—Field-magnet.

The Westinghouse Alternating-Current Arc-Light (Constant-Current) Dynamo (Fig. 98) resembles very closely the Westinghouse alternating incandescent machine in outward appearance, but its operation is quite distinct from the former, and is effected by the peculiar construction of the armature, which is designed so as to cause the machine to deliver a current of *constant strength* at all loads automatically. The armature is shown in perspective in Fig. 99, and in longitudinal and transverse sections in Figs. 100 and 101. It will be noted that the armature-coils are not, as in the incandescent machine, in the shape of flat coils placed on the periphery, but consist of oblong coils, which are wound separately, as shown in Fig. 102, and then by means of the clamping-tool (Fig. 103) are clamped in position around the cores of the armature-projections, which are provided with overlapping teeth. After the coils have been placed in position the spaces between the teeth are filled out with wooden wedges, which are dovetailed and slid in from the side, so that no further fastening is required to keep the coils or the wedges themselves in position. The peculiar construction of the armature with the overlapping teeth has the effect of maintaining the current constant at all loads, so that there is no regulating apparatus whatever required for that purpose. The armature is built up of thin wrought-iron sheets stamped out to the required shape, and the teeth are so designed, and are of such length, that they slightly overlap the distance between two consecutive pole-pieces, so that one tooth is not out of the field of any one magnet before another enters that field.

At the side of the dynamo in Fig. 98 there will be noted an apparatus consisting of a solenoid with a single core. It is a short-circuiting apparatus, and its object is to protect the machine from the results of a break in the line. In the continuous-current machine a break

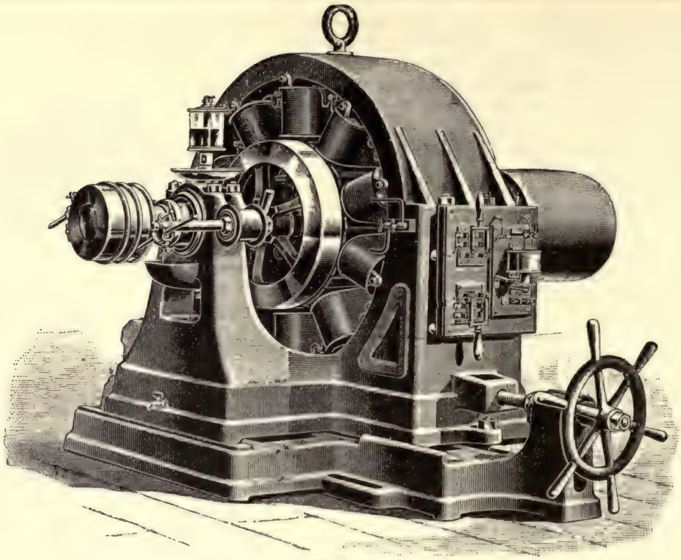


FIG. 98.

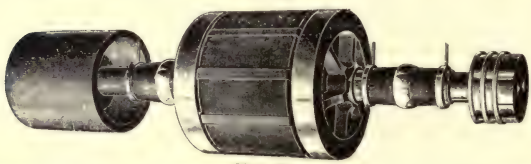


FIG. 99.

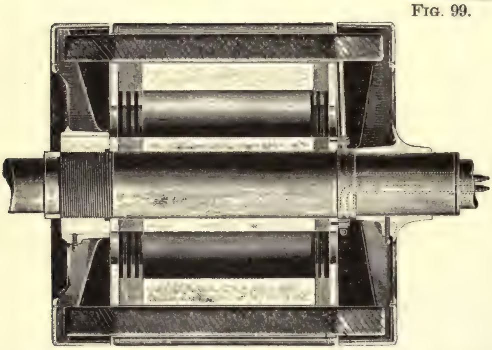


FIG. 100.

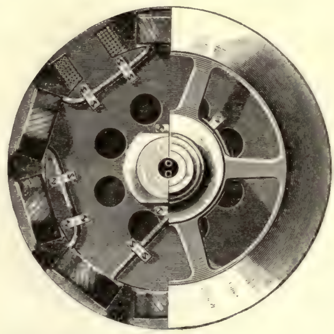


FIG. 101.

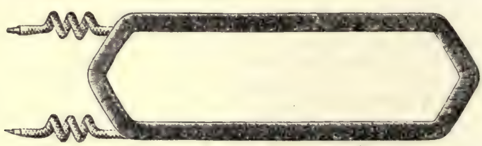


FIG. 102.

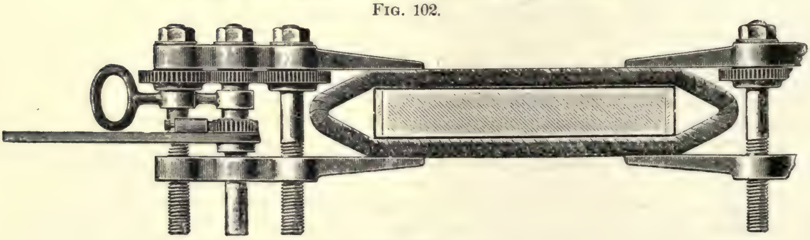


FIG. 103.

FIGS. 98-103.—Westinghouse alternating-current arc-light dynamo.

in the line is generally followed by the cessation of current in the armature when a series-machine is employed; but in this system a break in the external circuit causes the generation of a heavy current in the armature, which, if not prevented, would eventually cause its destruction. To avoid this, the apparatus shown is employed, and its function is to short-circuit the armature. By this means the counter-electromotive force generated in the armature is such as to cut down the heavy current to the normal strength, so that no dangerous heating of the armature-coils can take place. The apparatus is so constructed that an excess of electromotive force generated in the armature, such as would be caused by a break in the line, causes a spark to pass between two points; this allows sufficient current to pass to energize the solenoid, which pulls up its core and makes contact between two points that short-circuit the armature. Normally, the distance apart of these points is so regulated that any excess of current beyond 12 ampères causes the spark to jump and effect the short-circuiting.

There is still another safety device of the same nature, which consists of two metal points placed opposite each other on the armature-shaft, and connected respectively to the collector-rings. Upon the current exceeding a certain value the spark formed between these two points causes a short-circuiting of the machine, and a consequent cutting down of the current due to the increased self-induction.

The machines built vary in capacity from 25 lights to 240 lights, and the table shows their various sizes and capacity. It will be noted that the speeds of these machines are considerably lower than those employed in the incandescent system, and that the number of alternations per second is also far below that of the former, the average number approximating 7,500 alternations per min., as compared with 16,000 for the incandescent machines. The machines Nos. 2 and 3 are provided with two sets of windings connected to two pairs of collectors, so that two independent circuits can be run from one machine.

Sizes and Capacity of Westinghouse A. C. Arc-Dynamos.

	Number of lights.	Number of coils on arm.	Number of pole-pieces.	Speed.	Ampères.
No. 00	25	6	6	1,275	10
No. 0	40	8	8	950	10
No. 1	60	10	10	760	10
No. 2	120	12	12	650	30 } 2 circuits.
No. 3	240	16	16	480	30 } 2 circuits.

Kingdon Inductor Dynamo.—This dynamo (Fig. 104) has been designed to meet the wants of electric-supply stations employing the alternating transformer, or the alternating direct system. The main feature of the "inductor" dynamo is that all the bobbins of electric con-

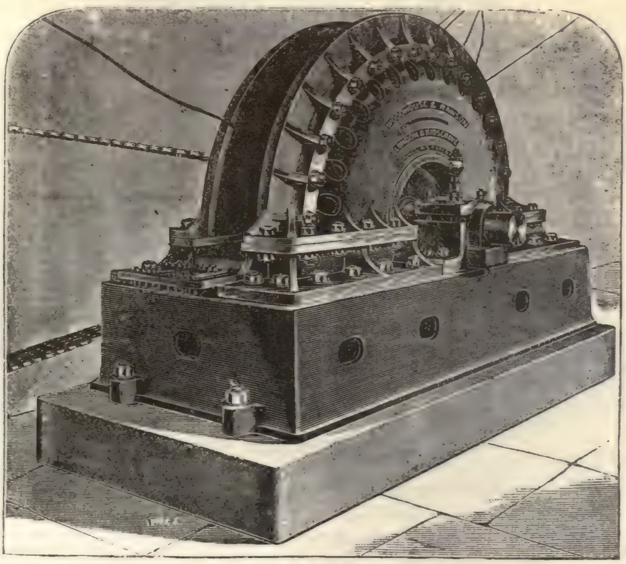


FIG. 104.—Kingdon inductor dynamo.

ducting wire are fixed; there are therefore no brushes or loose contacts. The number of bobbins in use may be easily varied to suit the requirements of the supply; another advantage is that, owing to the bobbins being fixed, even with high-tension currents, there is very small risk of destroying the insulation of the machine. An "inductor" dynamo of

normal size—i. e., 50 kilowatts—has 32 coils wound, and mounted on 32 cores (radial), which are composed of plates of thin, very soft charcoal-iron, magnetically insulated one from the other. Sixteen of these coils represent the field-magnets of the dynamo, while the remaining 16 intermediate ones correspond to the armature-bobbins of other machines. The cores and poles of both field-magnets and armature-bobbins are arranged radially, surrounding the only moving part of the dynamo, which is called the "inductor-wheel" (Fig. 105), which is the rotating part of this dynamo. It consists of 16 masses of laminated soft charcoal-iron, called inductor-blocks, also mechanically insulated, which are mounted on the circumference of gun-metal fliers or wings, which in turn are clamped between two steel plates, mounted on a boss keyed on to the main driving-shaft. Each indicator-block is just long enough to be embraced by the poles of one field-magnet and one armature-bobbin. The field-magnets are separately excited. The energy consumed for this purpose does not, as a rule, exceed 2 per cent of the maximum output of the machine. By rotating the soft-iron inductor-blocks before the respective poles of the field-magnets and armature-bobbins, rapid periodic reversals of the polarity of the armature bobbin-pole are effected. This produces alternating currents in the armature-coils. Between the inductor-blocks and the above-mentioned pole-pieces there is only just sufficient clearance to allow of free rotation; consequently the resistance of the magnetic circuit of the air-space is a minimum, while the soft character of the iron in the inductor-blocks and the magnet and armature-cores tends also to make this loss as small as possible, thus producing a very efficient machine at a low speed.

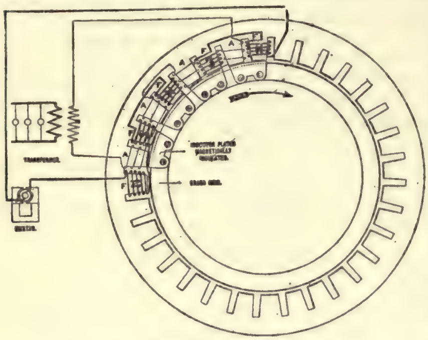


Fig. 105.—Inductor-wheel.

Fig. 106 illustrates the *Kennedy alternator*. The machine very much resembles a transformer in its parts, and is about as simple in construction. The iron field-magnet portions

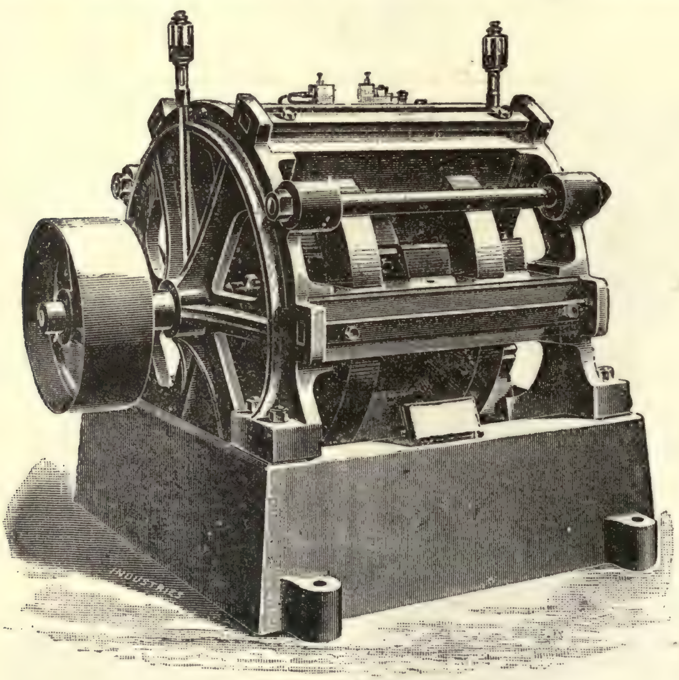


Fig. 106.—Kennedy alternator.

surround the copper coils, which are simple rings of insulated wires; the inductors are carried on gun-metal wheels, and in revolving alternately open and close the magnetic circuit round the copper coils, thus inducing current in them. There is no reversal of magnetism in any part of the operation of the machine, only a simple rising and falling of the magnetic flow without reversal. The iron is made of very ample sections, so that the induction is never high, and never falls to zero. The excitation is constant, but the induction varies with the

position of the inductors. There are two pairs of coils in the machine, and two sets of inductors, placed as shown in Fig. 107. The generating coil is wound first and insulated, then the exciting coil is wound over that, and the whole is insulated and fixed in the machine in the recesses formed in the field-blocks. By using two pairs of coils and two sets of inductors, and exciting the coils so that the field-blocks are magnetized with a pole in the middle and similar poles at each end, when the two exciting coils are in "series" with each other, any inductive effects on the one exciting coil are exactly and entirely neutralized by those effects on the other exciting coil. The two generating coils can be coupled either in series or in parallel, but the exciting coils must always be in series. This machine is very simple and inexpensive to build, and there is no difficulty with insulation or in constructing them for any pressure or frequency required. In large dynamos there are four pairs of coils and four sets of inductors. In the machine illustrated the inductors are 21 in. in diameter, the coils being 21¼ in. inside diameter; the electromotive force of the generating coil is about 1·35 volts per ft., working at very moderate inductions and at moderate speed, and this can be safely raised to 2 volts per ft. For low-pressure alternating currents this machine is equally applicable. A machine with inductors 4 ft. in diameter gives an output of 150,000 watts (100 volts 1,500 ampères) at a speed a little over 200 revolutions per min. This is suitable for low-pressure distribution near the station, and high-pressure at a distance by means of step-up transformers.

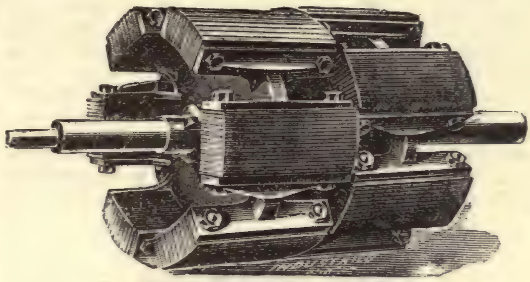


FIG. 107.—Kennedy inductors and coils.

Machines in which iron masses alone and no conductors are moved have also been constructed by Wheatstone, Henley, Elihu Thomson, Forbes, Klimenko, and others.

The Oerlikon Three-Phase Alternator.—This machine (Fig. 108), designed by Mr. C. E. L. Brown, was employed as the generator in the celebrated installation of power-transmission

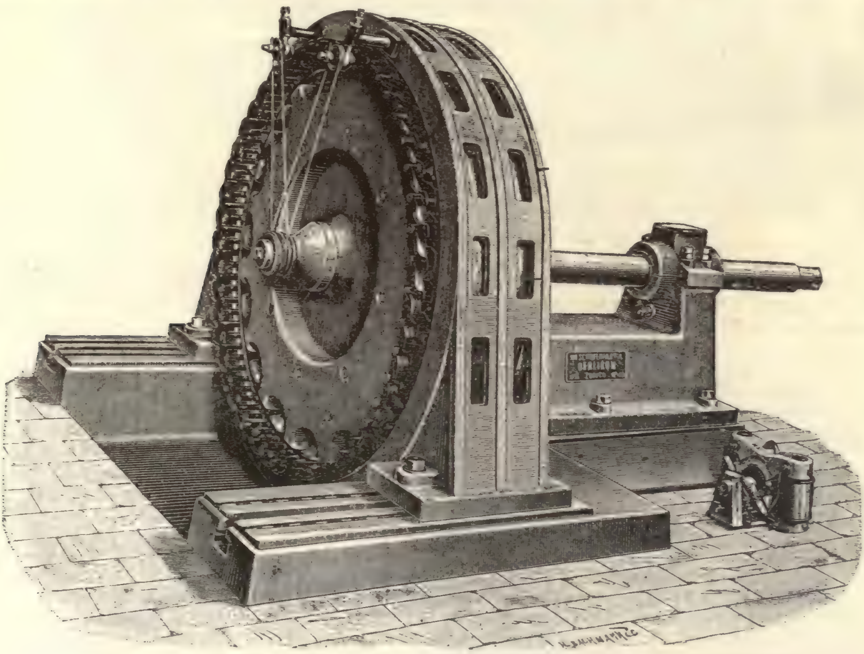


FIG. 108.—Oerlikon three-phase alternator.

between Frankfort-on-the-Main and Lauffen-on-the-Neckar, 1891, a distance of 112 miles. The machine was designed for 300 horse-power, running at a speed of 150 revolutions per min. The armature-circuits are arranged to give three alternating currents, lagging 120°, one behind the other. Each of the three circuits of the machine is wound for a pressure of 50 volts and a current of 1,400 ampères. The current output being large, rubbing contacts have been avoided by making the armature stationary and the field-magnets revolve. The arma-

ture-conductors are 29 mm. in diameter, and consist of massive bars of copper, insulated inside with asbestos tubes, and buried in holes punched out of the iron close to the internal periphery. Foucault currents, which would attain enormous values in such large copper conductors, if they were arranged in the ordinary way, are by this device avoided; in fact, experiments made with "buried" conductors, 50 mm. in diameter, did not show that any power was lost by Foucault currents. This method of arranging the armature-conductors is mechanically strong, and, as it enables asbestos to be used as an insulator, results in an armature which is absolutely incombustible. Moreover, the reduction in the air-space, and the consequent improvement of the magnetic circuit, reduces the exciting current.

Corresponding to the 32 poles of the field-magnet, each circuit of the armature has 32 copper bars, connected in series by transverse pieces. There are therefore, in all, 96 (3×32) bars on the armature. The three circuits are joined up to each other in a manner similar to the three circuits of the Thomson-Houston arc-machine. The armature-core is surrounded by a cast-iron frame, and the whole can be moved along the bed-plate for cleaning and other purposes, leaving the field-magnet open to view, as shown in Fig. 109.

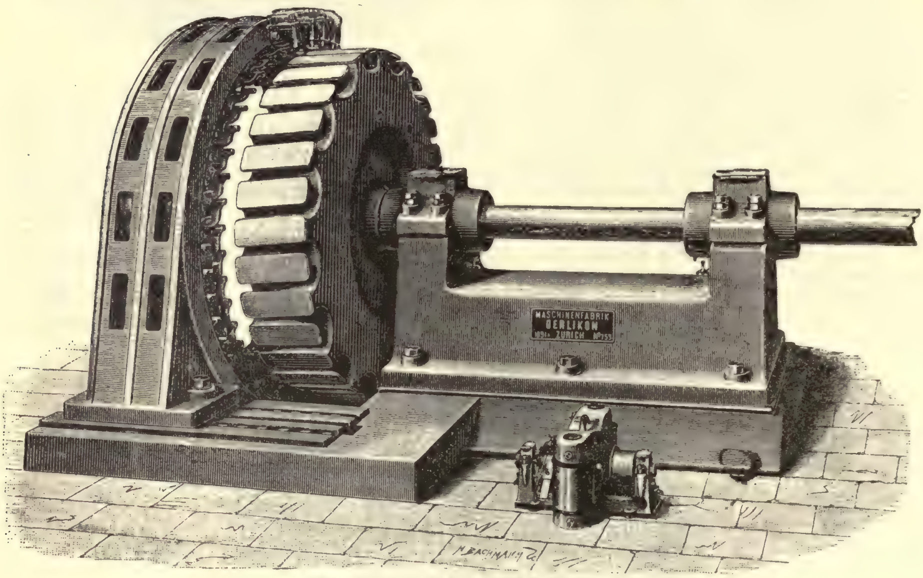


FIG. 109.—Armature and field-magnet.

The exciting circuit is coiled round a sort of cast-iron pulley. Two steel rims, each armed with 16 horns forming pole-pieces, are bolted on to the pulley, one on either face, in the manner shown in detail in Fig. 110. This arrangement permits of the maximum utilization of the magnetic flux, and both the copper and the exciting current are reduced to a minimum. The construction of a field-magnet of this type is very simple, the 32-pole magnet being in only four separate parts—a great advantage in a piece of moving mechanism subject to heavy stresses. The exciting current is taken to the field-magnets by means of two metallic bands, each of which passes round a grooved ring on the spindle, and round a pulley connected to a terminal. (See Fig. 108.) The armature is overhung, the massive spindle being carried on a double bracket bolted to the bed-plate. A machine of this type can work equally well as a synchronizing motor, but it differs from an ordinary alternate-current motor, inasmuch as it can be made to start without difficulty.

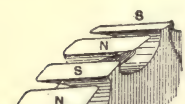


FIG. 110.—Detail.

The total weight of copper on the field-magnet is only 300 kilogrammes. To excite the machine so as to give 50 volts on open circuit, only 100 watts are required: that is to say, $\frac{1}{20}$ per cent of the output. At full load, owing to the reaction of the armature, this amount is slightly increased, but it never exceeds a fraction of 1 per cent. At full speed and with normal volts the friction losses amount to 3,600 watts, about 1·6 to 1·7 per cent of the maximum output. The $C^2 R$ loss in the armature-conductors at full load is 3,500 watts. This gives a total efficiency of 96 per cent. The total weight of the machine without bed-plate is 9,000 kilogrammes.

The efficiency of the dynamo is greater than that of any other converter of energy. The test of such machines, made by a committee of the Franklin Institute, in connection with the Electrical Exhibition of 1884, gave the following results:

	Volts.	Ampères.	Weight.	TOTAL EFFICIENCIES.				COMMERCIAL EFFICIENCIES.			
				Full load.*	¾ load.	½ load.	¼ load.	Full load.*	¾ load.	½ load.	¼ load.
Edison No. 4.....	125	80	1,470 lbs.	94·45	93·26	89·65	83·89	88·44	87·40	83·65	76·40
Edison No. 5.....	125	100	2,475 "	96·01	.....	.....	.....	89·19	.....	.....	.....
Edison No. 10....	125	200	4,710 "	94·68	92·44	90·55	83·32	89·61	88·23	86·12	77·53
Edison No. 20....	125	400	8,341 "	96·65	95·46	92·77	88·80	91·96	91·19	88·93	83·76
Weston 6 M.......	120	80	2,000 "	94·67	96·53	94·84	89·33	87·66	90·10	89·23	82·87
Weston 7 M.......	160	125	3,300 "	96·56	96·38	94·84	90·08	89·37	90·49	89·57	84·37
Weston 6 W. I....	130	100	2,100 "	96·20	94·06	92·89	91·64	90·85	89·22	87·32	84·07

For more complete and detailed descriptions of dynamos, the reader is referred to the following: Prof. Sylvanus P. Thompson, Dynamo Electric Machinery; Dredge, Electric Illumination; Esson, Magneto- and Dynamo-Electric Machines; Schellen, Magneto- and Dynamo-Electric Machines; Atkinson, Electric Lighting; Kapp, Electric Transmission of Energy; Fleming, The Alternate-Current Transformer; Kapp, Alternate-Current Machinery; Mordey, Alternate-Current Working, *Jour. Inst. Elec. Eng., London*, vol. xviii., p. 583, *et seq.;* Kapp, Predetermination of the Characteristics of Dynamos, *Jour. Soc. Tel. Eng.*, 1886; E. Hopkinson, The General Theory of Dynamo Machines, *British Assoc.*, Manchester meeting, 1887; J. Hopkinson, *Proc. Roy. Soc.*, 1885, Part II. See also *Trans. of the Am. Inst. of Elect. Eng.*, *Jour. Inst. of Elect. Eng.*, London; and to the files of *The Electrical Engineer*, N. Y., *Electrical World*, *Electrician*, *Electrical Review*, *La Lumière Électrique*, and other electrical journals.

DYNAMOMETERS. *Alden's Absorption Dynamometer.*—Mr. George I. Alden (*Trans. A. S. M. E.*, vol. xi) describes a new automatic absorption dynamometer, shown in Fig. 1, as follows:

"This dynamometer is essentially a friction-brake, in which the pressure causing the friction is distributed over a comparatively large area, thus giving a low intensity of pressure between the rubbing surfaces. The pressure is produced by the action of water from the city pipes. Enough water is allowed to pass through the machine to carry off the heat due to the energy absorbed. The rubbing surfaces are finished smooth and run in a bath of oil. A valve operated by the slight angular motion of the dynamometer varies the supply of water, and consequently the pressure between the frictional surfaces, thus securing automatic regulation.

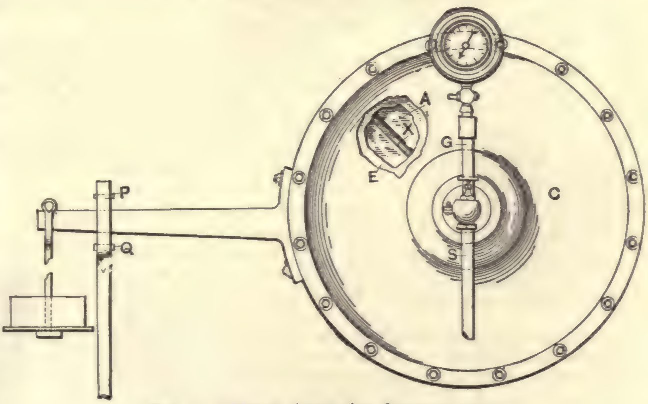


FIG. 1.—Alden's absorption dynamometer.

"Referring to Fig. 1, *A* is an iron disk keyed to the crank-shaft. The sides of this disk are finished smooth, and each side has one or more shallow radial grooves, as shown at *X*. The outer shell consists of two pieces of cast iron *C C* bolted together, but held at a fixed distance apart by an iron ring and by the edges of the copper plates *E E*. Each of these plates at its inner edge makes with the cast-iron shell a water-tight joint, so that between each copper plate and its cast-iron shell there is a water-tight compartment, into which water from the city pipes is admitted at *G*, passes to the opposite compartment and is discharged through a small outlet. The inner chamber is filled with oil, which finds its way along the grooves in the disk *A*. The shaft is free to revolve in the bearings of the cast-iron shell *C C*. The shell has an arm carrying weights, which has its angular motion limited by stops at *P* and *Q*. An automatic valve regulates the supply of water to the machine and is so adjusted that a slight angular motion of the brake varies the free water passage through it. The outlet aperture being small and constant, the pressure of the water in the compartments is thus automatically varied.

"The dynamometer is operated as follows: The inner chamber being filled with oil, weights are suspended from the arm to give the desired load. The engine is started, and when up to speed a valve is suitably opened in the water-pipe leading to the automatic valve, which latter, being open, allows water to pass to the outer compartments. The pressure of this water forces the copper plates against the sides of the revolving disk *A*—with which they were already in contact—causing sufficient friction to balance the weights upon the arm, which then rises. This motion operates the automatic valve, checking the flow of water to

* Average of full load measurements.

the brake and regulating the moment of the friction on the disk to the moment of the weights applied to the arm of the brake."

The Richards Absorption Dynamometer, designed by Mr. C. B. Richards, consists of a tank $A\,B$ (Fig. 2) within which two paddle-wheels revolve in oil, thus producing a resistance and a tendency to rotate the whole tank, which is mounted on friction-rollers. This tendency to rotate is measured by the lever-arm acting on a platform scale. By means of a valve the oil in the tank can be allowed to circulate with greater or less freedom; by closing the valve a pressure is brought to bear on the oil in the tank, so that the resistance to the rotation of the inner wheels thus becomes a drag on the driving power; when the maximum resistance is obtained without decreasing the number of revolutions per min. of the shaft, the force of resistance, measured on the scale-beam, will enable us to calculate the horse-power consumed. In order to prevent any change of temperature in the oil, a constant stream of water is discharged on to the tank through a perforated pipe P above it. Beneath the tank proper a metal receiver R catches the water, which is then carried off by the waste-pipe W, shown at the bottom of the receiver.

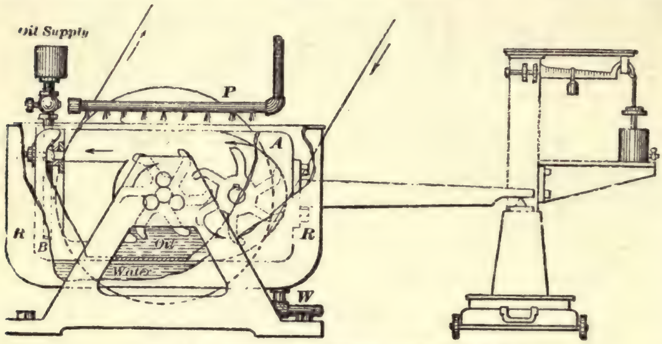


Fig. 2.—Richards's absorption dynamometer.

Tatham's Belt Dynamometer is shown in Fig. 3. In this apparatus the difference in tension of the slack and driving sides of the belt is exerted to vibrate a system of lever-arms and scale-beam. The belt from the shaft drives the dynamometer in the direction indicated by the arrows, a and a' being respectively the tight and loose belts, or rather sides of the belt, driving the pulleys E and E' on the vibrating frame B. The vibrating frame B is balanced upon knife-edges at C, and is provided with similar knife-edges at H, which engage the links of the scale-beam. The distance from C to H is equal to the effective diameter of the pulleys E and E' upon the vibrating frame; a pulley M keyed to lower shaft communicates motion to the machine to be tested, the direction of belt being as shown.

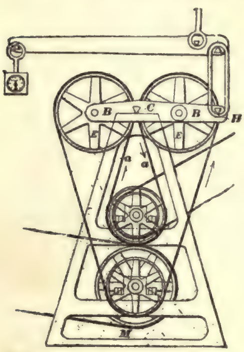


Fig. 3.—Belt dynamometer.

Amsler's Recording Dynamometer (Fig. 4) consists of two arms, one of which is keyed on the driving-shaft and the other on the following-shaft, the two shafts being in line end to end. The arms are connected by spiral springs, the compression of which measures the effort transmitted, and to avoid violent vibrations a dash-pot is fitted inside the coils of one of the springs. To record the compression of the springs the arm of the dynamometer carries a set of three drums, from the first of which a roll of paper is gradually unwound as the dynamometer revolves, and passing over the second drum is recoiled on the third. A pencil connected with one of the two spiral springs marks the paper as it passes over the second drum. The method adopted for working the drums is peculiar. A weighted lever vibrates on its center through a limited arc as the dynamometer revolves, thus actuating a ratchet, which in turn moves the drums forward step by step; this simple device has been found to act most satisfactorily up to a speed of 150 revolutions per minute.

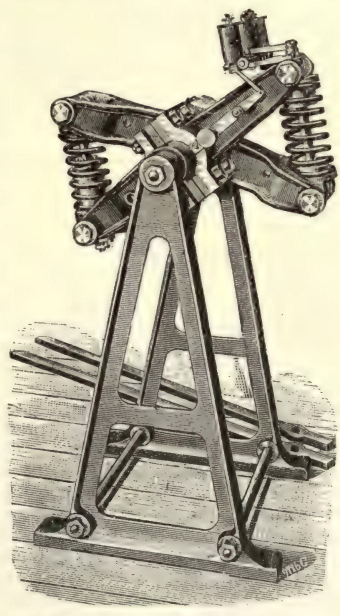


Fig. 4.—Amsler's recording dynamometer.

Ejector: see Harvesting Machines, Grain and Injectors.

EJECTOR, PNEUMATIC. An apparatus for removing sewage used in the so-called Shone system. The sewage from a given district is finally collected into one pipe, shown at the left of Fig. 1, and flows into the ejector at the bottom.

When the ejector is filled, an automatic action is established which admits compressed air, brought to the ejector from a central compressing station, which may be, as at Eastbourne, England, three miles away. The compressed air acts on the contained sewage in the air-tight ejector with the requisite pressure, driving it out of the ejector into the sewage-main, no matter how high the latter may be above the ejector level. The sewage being ejected, the action of the automatic gearing is reversed, which cuts off the supply of compressed air, and permits the air in the ejector to escape into the sewers, to aid in their ventilation. The sewage then flows in again, and the action is repeated as often as is necessary, depending entirely upon the volume of flow.

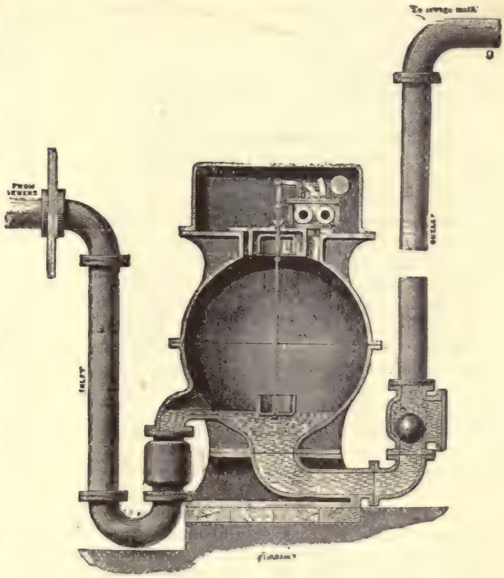


FIG. 1.—Shone's pneumatic ejector.

It will be observed that the compressed air is not admitted until the ejector is full, and the air is not allowed to exhaust until the ejector is emptied down to the discharging level. In consequence of these actions the sewage is got rid of just as fast as it is produced.

The air is compressed in a central station by the use of steam-boilers or gas-engines, the air, after compression, being stored in iron receivers or in the air-mains themselves, if of sufficient length. It is carried to each ejector in small iron pipes.

By the use of the pneumatic ejector, basements can be drained even when far below the main sewer.

It may also be used to raise water to tanks on the tops of large buildings, for elevator and domestic supplies.

With regard to the economy of pumping with compressed air, the following table gives the percentage of useful effect which, it is claimed, can be obtained in the ejectors for various heads:

Head.	Percentage of useful effect.	Head.	Percentage of useful effect.
20	61	60	45 5
40	52	80	42
50	49	100	38·5

It is also stated that, from actual diagrams taken from a pair of small steam-cylinders 10½ in. in diameter, compressing air in a pair of 14-in. cylinders to a pressure of 24 lbs. to the sq. in., which corresponds to a head of 55 ft., 50 per cent of the total indicated horse-power exerted in the steam-cylinder has been got in actual work in the ejector.

Electric Coal-Mining: see Coal-Mining Machines. **Electric Crane**: see Cranes. **Electric Elevator**: see Elevators. **Electric Locomotive**: see Electric Motors. **Electric Production of Aluminium**: see Aluminium. **Electric Pump**: see Pumps, Reciprocating. **Electric Railway**: see Railways, Electric. **Electric Regulator**: see Car-Heating. **Electric Riveting**: see Welding, Electric. **Electric Rock Drill**: see Drills, Rock. **Electric Sole Sorter**: see Leather Working-Machines.

Elevators: see Mills, Silver and Ore-Dressing Machinery.

ELEVATORS. These may be divided into lifting devices (1) for passengers and freight; (2) for grain and coal; and (3) for canal-boats. Passenger and freight elevators may be classed with relation to their motive power as steam elevators, hydraulic elevators, and electric elevators. In addition, under the generic term may be included numerous devices for special lifting purposes, which are not CRANES (which see).

I. PASSENGER AND FREIGHT ELEVATORS. STEAM ELEVATORS.—A simple form of steam freight elevator, manufactured by Otis Brothers & Co., of New York, is represented in Fig. 1. It is particularly adapted to buildings where high-pressure steam is available, and is intended for handling heavy freight. W is the steam hoisting-engine, B the elevator platform, C the overhead sheave, and L the pipes leading steam from boiler to engine. The arrangement of the vertical inverted engines and hoisting-drum of this elevator is shown in Fig. 2.

The Belt Elevator System is represented in Fig. 3. A is the elevator, B the platform, E the motor-engine, and C the overhead sheave.

Elevating Deck Ferry-Boat.—Figs. 4 and 5 illustrate a novel ferry-boat of English construction, in which the entire deck is elevated. The deck is actuated by bevel and worm gearing, so that at any state of the tide it may be brought to the same level as the quay for the shipment of vehicles, etc. The elevating deck is 78 ft. long and 32 ft. broad. The ele-

vator apparatus is worked by triple-expansion engines, which actuate shafting geared to each of the vertical screws. The lift is 14 ft. (See *Engineering*, Sept. 5, 1890.)

II. Hydraulic Elevators.—Figs. 6, 7, and 8 represent the principal types of these machines as made by Otis Brothers & Co. Fig. 6 shows the street-pressure system adapted to cities where there is a steady water-pressure in the mains. *A* is the hydraulic cylinder, *B* the elevator-car, *C* the overhead sheave, and *D* the controlling rope. The arrangement of water-supply and waste-pipe will readily be understood. For use in cities where there is no public water-supply under pressure, the apparatus represented in Figs. 7 and 8 are provided, in Fig. 7 known as the pressure-tank-in-basement system. *A* is the hydraulic cylinder, *B* the car, *C* the overhead sheave, *D* the controlling rope, *E* a pump (steam or gas), *F* a tank in the basement to receive the discharged water from the cylinder, *G* an iron pressure-tank, *H* the supply-pipe to the cylinder through the valve, *I* the water-pipe from the pump which fills the pressure-tank, *K* the cylinder discharge-pipe, and *L* the steam-pipes leading from pump to boiler.

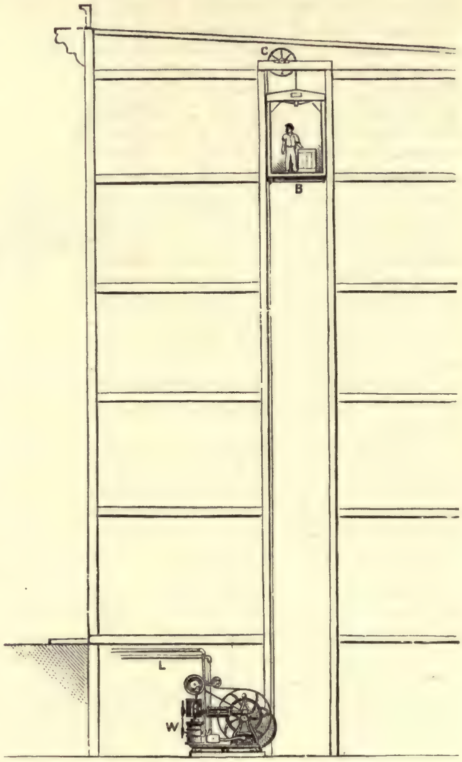


Fig. 1.—Steam freight elevator.

Fig. 8 shows a combined gravity and pressure-tank-on-roof system, which differs from that last described in the arrangement of the tank *G* on the roof instead of in the basement, and the consequent utilization of the gravity of the descending water.

The latest form of Otis hydraulic elevator is illustrated in Fig. 9. The principal novel features here are the pilot-valve and the port-stop. A lever in the car is connected by a suitable device with the valve-sheave, so that a movement of the lever gives a corresponding movement of the sheave, and through it to the pilot-valve. The valve operates in the following manner: The area of the upper piston is twice that of the lower piston; therefore, when the small pilot-valve is raised by the lever (thus opening communication between the upper part of the large valve-cylinder and the discharge-tank) the main valve will move up: but the moment the valve begins to move, it commences to close the pilot-valve port, thus cutting off the discharge at a point proportionate to the movement of the lever in the car. By lowering the pilot-valve, water is admitted to the upper part of the large cylinder, and the valve descends in the same manner as above. The port or apron stop consists of aprons on top and bottom of piston, with holes drilled in them in a progression such that when the apron advances over the upper or the lower port the area for the outflow of water is gradually diminished, in a ratio such that the retardation of the piston is uniform throughout the length of stop, therefore bringing the car to a gradual stop.

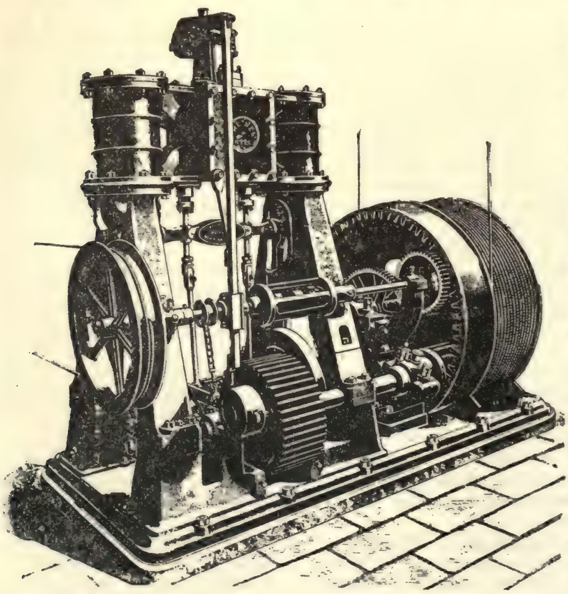


Fig. 2.—Elevator engine.

The Hydraulic Elevators in the Eiffel Tower. — The Eiffel

Tower is erected on the Champs-de-Mars, Paris, and originally formed one of the buildings of the French Exposition of 1889. It consists essentially of a pyramid composed of four great curved columns independent of one another, and connected only by belts of girders at the different stories until they unite toward the top of the structure, where they are joined by ordinary bracing. The material used in the construction is iron. The principal data concerning this building—at the time of its erection the most lofty in the world—are as follows: Total height, 984 ft.; weight of iron used, 7,300 tons; number of pieces of iron of different forms employed, about 12,000; total thrust on foundations, 565 tons—or, under maximum wind-pressure, 875 tons.

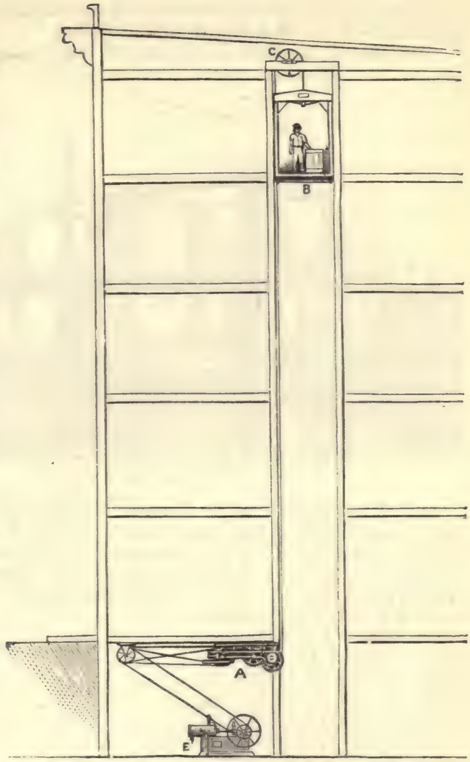


FIG. 3.—Belt elevator

The elevators used in the Eiffel Tower are arranged in the following manner: Two elevators on the Roux, Combaluzier, and Lepape system, with chains of jointed rods, lift from the ground to the first platform, working alongside the staircases in the east and west piers. Two elevators on the Otis plan work in the north and south piers, starting likewise from the ground and rising to the second platform at 380 ft. height, with option of stopping at the first platform. Lastly, by an elevator on the Edoux system, placed vertically in the center of the tower, visitors are raised from the second platform to the third at a height of 906 ft. above the ground.

The Roux elevator follows a curved path, and therefore the otherwise rigid actuating piston is replaced by a jointed one, which may be compared to a vertebral column. It is, in fact, composed of a series of links having the form of connecting rods, attached to each other by knuckle-joints. These links are, besides, furnished with two guiding friction-rollers at each point of attachment. The link, thus articulated, is introduced into a round or square guide-way, in which it runs easily, and follows all sinuosities as well as if it were a chain worked by traction. By fixing a link of this chain to the floor of an ordinary elevator-cage, and impelling the flexible chain by means of a suitable wheel, driven by any motive-power whatever situated at the bottom of the elevator, it is easy to see that the chain will follow the cage wherever its guides will permit it to run. By joining the two extremities of the flexible chain, it forms an endless chain of rods moving over two encaged wheels. The lower wheel applies the power, and the upper one acts as a simple pulley-wheel to enable the chain to circulate.

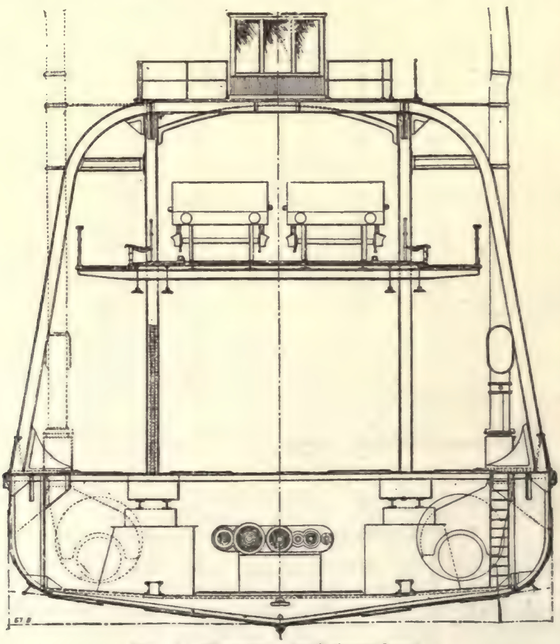


FIG. 4.—Elevating deck ferry-boat.

The Otis elevator is of the hydraulic type described elsewhere, the power being derived from a hydraulic cylinder 36 ft. long, having a 38-in. piston with two $4\frac{1}{2}$-in. rods, the upper ends of which are fastened to a truck Y carrying six grooved pulleys 5 ft. in diameter. The hydraulic

cylinder is single-acting, water being admitted to the top only. The cabin, truck, and safety appliances make up a weight of 23,900 lbs.

The Edoux elevator has a pair of cabins working vertically and balancing one another. The hydraulic cylinder is vertical, and about 230 ft. long. The upper cabin is carried on two hydraulic rams.

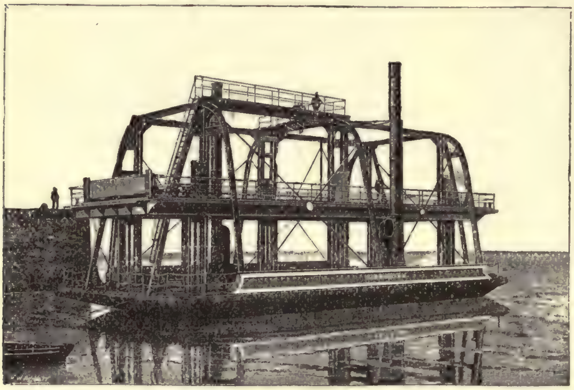


Fig. 5.—Elevating deck ferry-boat.

For full details of the Eiffel Tower elevators see *Proc. Inst. of Mech. Eng.*, July 2, 1889.

Electric Elevator.—The electric elevator, as made by Otis Brothers & Co., simply consists in the application of an electric motor to the hoisting-gear of the apparatus. The motor is so arranged as to start and stop with a gradual movement, and to consume power only in proportion to the load. The construction is clearly shown in Fig. 10.

III. Grain Elevators.—The elevator known as elevators A and B, belonging to the Armour Elevator Co., of Chicago, Ill., and receiving grain from the St. Paul road, is the largest elevator in the world under a single roof. Elevator D and its annex, belonging to the Armour Company, surpass it in capacity, but are not a single, unbroken structure. It is rated at a storage capacity of 2,500,000 bushels, can unload 500 cars per day, and deliver 100.000 bushels per hour to cars and boats. Cars enough to keep it at work for four days can be accommodated in the great yard annexed to it. The building proper is 550 ft. long and 156 ft. high. An engine of 1,200 horse-power is employed in driving the elevating-belts.

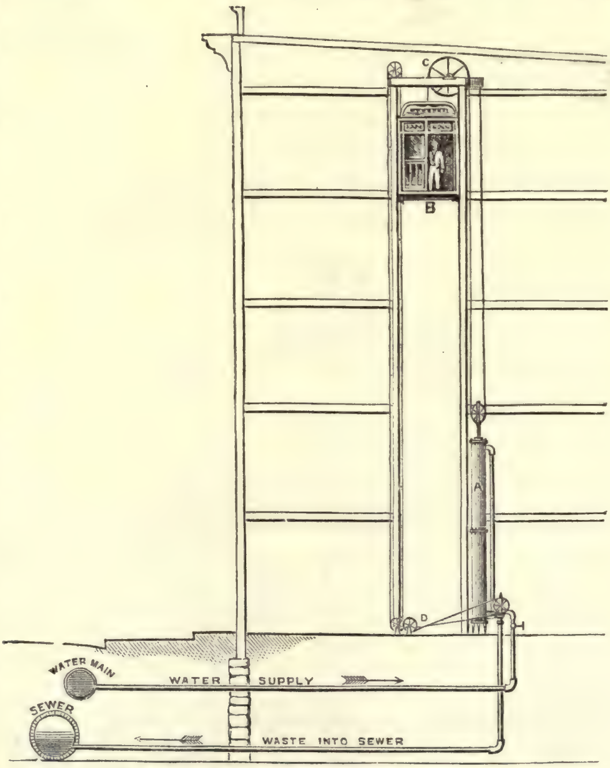


Fig. 6.—Hydraulic elevator—street-pressure.

The general features of its construction are the following: It comprises a main building surmounted by what is termed the cupola. The main driving-engine is situated on about the ground level, at one end of the building. Along the top of the cupola a counter-shaft, the full length of the building, is carried. This is driven by the engine. The main belt is of India-rubber and canvas, 8-ply in thickness and 60 in. wide. This runs very nearly vertically from the engine driving-pulley to the pulley on the counter-shaft 150 ft. above it. All along the countershafts are the driving-pulleys for working the 28 elevator-belts. These belts are made also of India-rubber belting, and carry steel buckets riveted at regular intervals along their outside face. As the belt travels up on one side it carries up full buckets. At the top these pass over the driving-pulley and are emptied as they turn over, and then they descend empty on the other side of the belt. From the point of delivery of the belt the grain passes by gravity through inclined chutes to the main body of the elevator, and is directed by one or the other of the chutes to any desired point. The grain from the elevating-belt falls into the mouth of a chute which rotates on a vertical axis, whose prolongation would pass

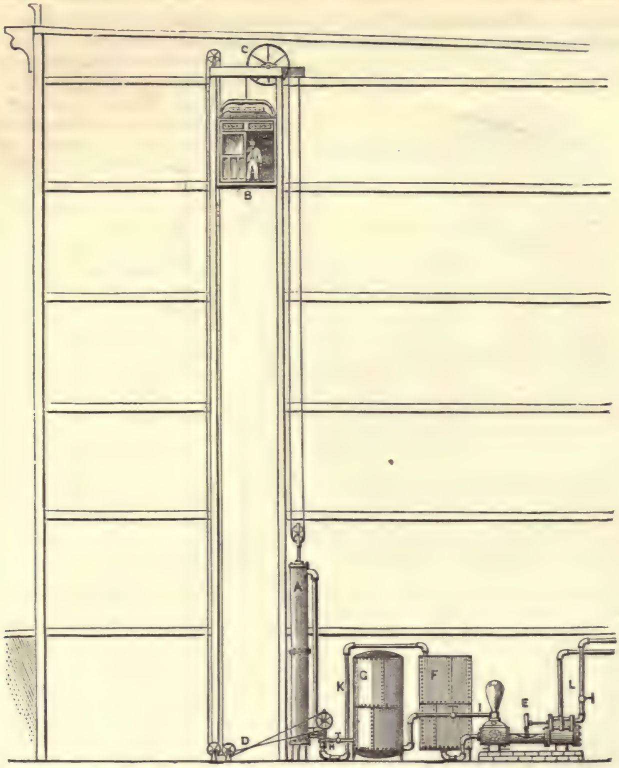


FIG. 7.—Hydraulic elevator—basement-pressure.

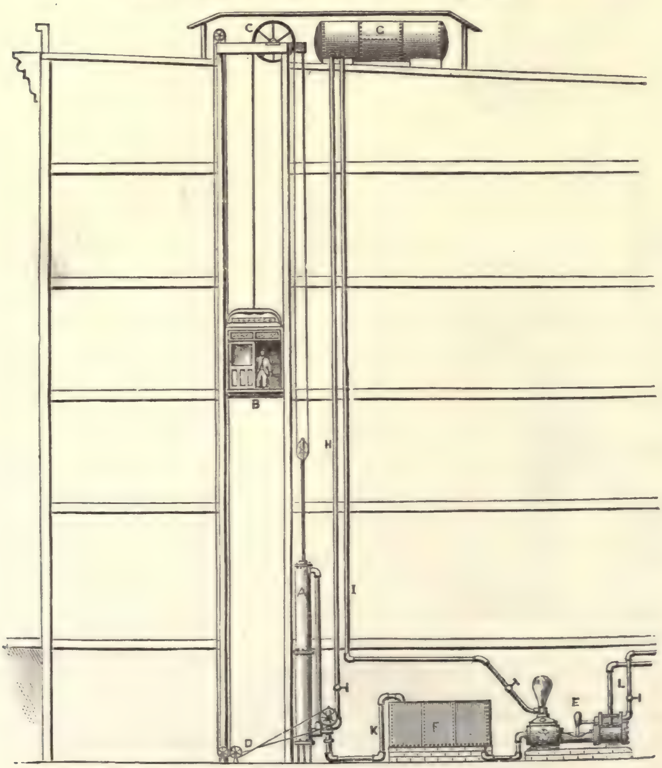


FIG. 8.—Hydraulic elevator—gravity- and roof-pressure.

through its receiving end or mouth. Thus, when swung around on its pivot, its receiving mouth remains unchanged in position. The open ends of a number of chutes leading to the garners corresponding to respective bins below are arranged in a circle around the revolving chute or "revolver." Each is numbered in accordance with the bin it leads to. The revolver can be swung so as to connect with any one of these. In this way one elevator is made to feed a number of bins.

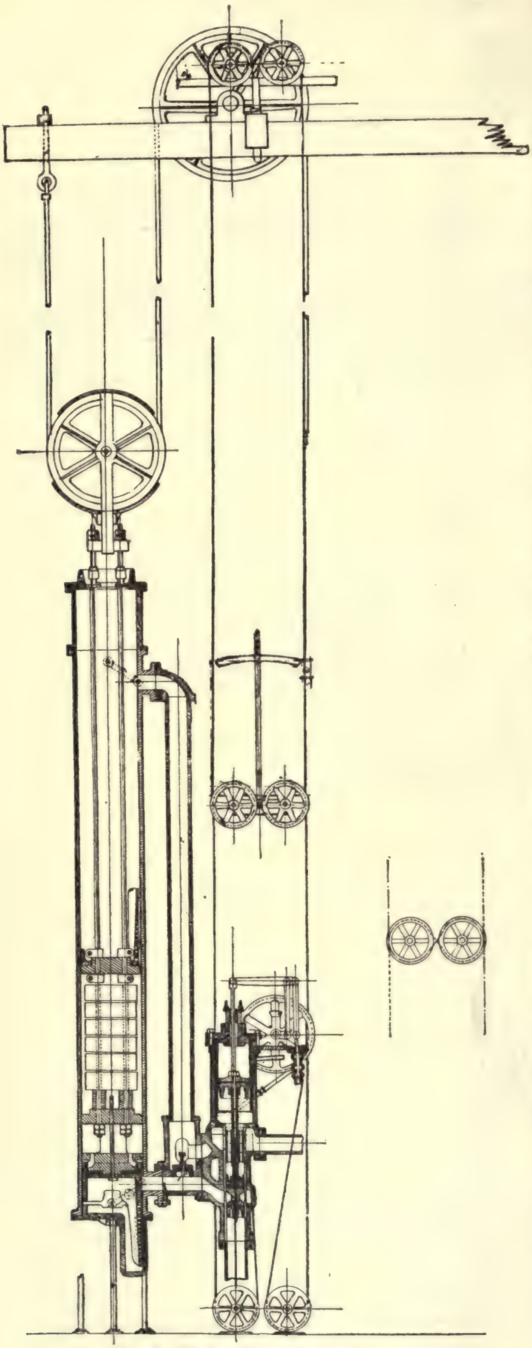


Fig. 9.—Hydraulic passenger elevator.

Below the chutes on the next floor are what are known, and have just been referred to, as garners. These are simply square bins holding 1,000 bushels each. Immediately under each is a platform-scale, with its bin of the same size as the garner above it, and receiving grain from the garner when desired. Here the grain is weighed. The garner, it will be seen, can receive grain during the operations of weighing and discharging the weighing-bin, and when the latter is emptied can at once refill it. From each weighing-bin the grain is delivered into the bins and pockets that completely fill most of the height of the main building. These range in size from 500 to 7,000 bushels capacity, so as to suit every requirement. Much of the grain received is simply graded, and an equivalent weight of grain of the same grade is delivered when called for. Other grain is to be received with its "identity preserved." In this case the specific grain, and no other, must be delivered on call. The great variety in size of bins adapts the elevator to this work. The garners, weighing-bins, and storage-bins have sloping bottoms, so that no grain lodges in them. An inclination of 6 in. in a foot is sufficient to insure this. Grain is weighed when received and when delivered. Each weighing operation involves the elevation of the grain from the lower floor, where the bins deliver it clear to the top of the building, for delivery through the revolver and fixed chute to the proper scale. Transfer-elevators are employed to effect the transfer of grain from one bin to another. These elevate it so that it can descend through inclined chutes in the desired direction. If the chute does not carry it far enough, one or more additional elevators and chutes are called into requisition. One function of the elevator is the cleaning of grain. Some of the bins, termed cleaning-bins, are equipped with winnowing-fans for blowing out dust and chaff, and with screens through which the grain has to pass. The latter remove the coarser particles. The winnowed and sifted grain then falls into the bin. The bins all terminate some distance above the ground-level. A train of cars has ample head-room below them. From the level of the bottoms of the bins to the weighing-floor the entire area is devoted to the honeycomb of bins, except the few small trunks through which the elevator-belts travel, or through which grain descends from

one tier of bins to the tier below. A space at one end is also free for the great driving-belt to travel in. The elevator-belts descend into hoppers below the ground-surface, into which grain to be elevated is delivered. At intervals along the platforms forming the bottom floor are trap doors giving access to these hoppers. Grain does not remain in these hoppers; it is at once elevated.

To deliver the grain from the cars into the elevator-hoppers there is used a scraping shovel about 3 ft. sq., to which a rope is attached. The rope leads to a steam apparatus, by which it is taken in at the proper time, as if on a windlass. The operator draws the shovel back into

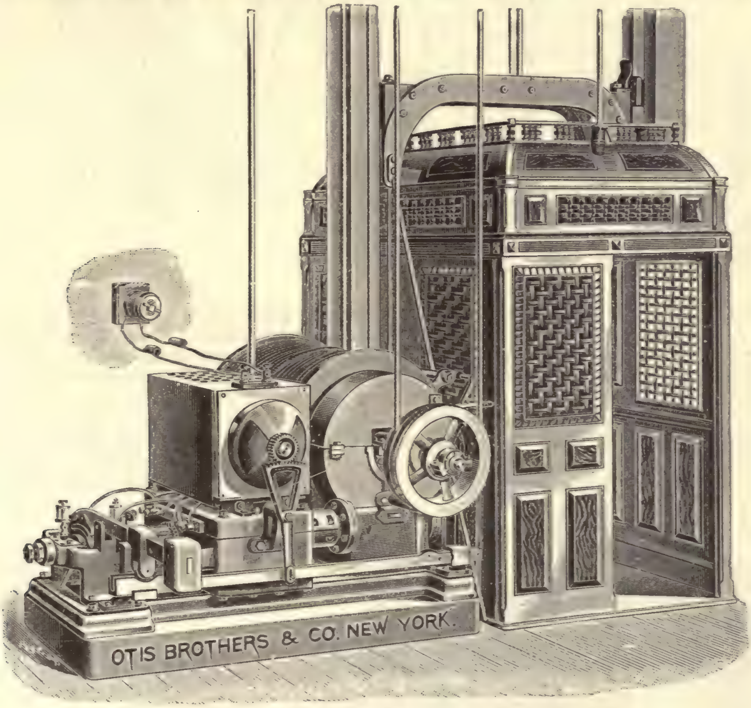


FIG. 10.—Electric elevator.

the car of grain, and holds it nearly vertical and pressed down into the grain. The rope draws along the shovel with the grain in front of it, and a number of bushels are delivered at each stroke. In this way a couple of men can very quickly empty a car. The movements of the shovels succeed one another with sufficient rapidity to keep the men in active movement. One of the features of this elevator is the use of the electric light, which is arranged to light the interior of cars, so that night-work can be carried on. In the recent heavy grain deliveries it was found necessary to work day and night.

The portion of such elevators containing the bins is built without framing. Planks are laid flatwise upon each other and spiked through to the layer below. In this way the outer walls and the bin divisions are built up, giving immense strength and power to resist lateral thrust. A usual timber for the sides is 2 × 8 in. spruce, giving 8-in. walls, and for the bins 2 × 6 in. is often employed. The Armour elevator contains over 8,000,000 ft. of wood, and about 4,000 kegs of nails were used in its construction. The main building is bricked in outside of the timber walls, and the roofs and cupola walls are covered with tin. It was erected between June, 1887, and March, 1888, being put in operation on the last-named date. It cost about $600,000.

The elevator described represents one of many similar structures situated in the principal cities of the United States, and designed to handle the enormous grain crops of the Western States and Territories. To give some idea of the extent of the business in our cities, the following statement of number of elevators and their capacity for some leading cities will be of interest:

NAME OF CITY.	Number of stationary elevators.	Capacity in bushels.	NAME OF CITY.	Number of stationary elevators.	Capacity in bushels.
New York	27	27,275,000	St. Louis	12	11,950,000
Chicago	26	28,675,000	Milwaukee	9	5,430,000
Duluth	14	19,200,000	Detroit	4	2,900,000
Minneapolis	16	13,290,000	Peoria	5	2,150,000

Coal-Hoist (Fig. 11) represents a novel form of coal-hoist, constructed by the Philadelphia and Reading Railroad, for coaling locomotives.

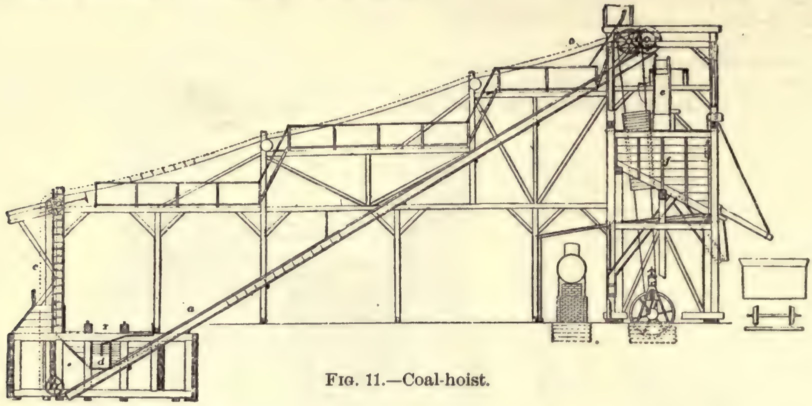


FIG. 11.—Coal-hoist.

The lower side of an endless-link carrier, *a*, runs in a trough, *t*, which extends from the coal-pit, *d*, to the top of the pockets. To this carrier, at intervals of about 30 in., buckets—or rather scrapers—are attached, which are shaped to fit the interior of the trough. A coal-car is pushed over the pit and dumped, and the coal runs by gravity through a chute at *d* in the end of the pit upon the carrier. There are three pockets in line, the center one being filled directly from the main trough, while the coal is carried into the others by short movable chutes, leading from the upper end of the main trough. Coal of any size is handled by the carrier. The engine is 15 horse-power. Power is transmitted from the engine by a link-belt to a geared pulley at the top of the hoist. This pulley engages with a sprocket-wheel which bears the carrier. The hoisting capacity is stated to be 90 tons of coal per hour. The usual load is 60 tons per hour; 100 locomotives can be coaled daily.

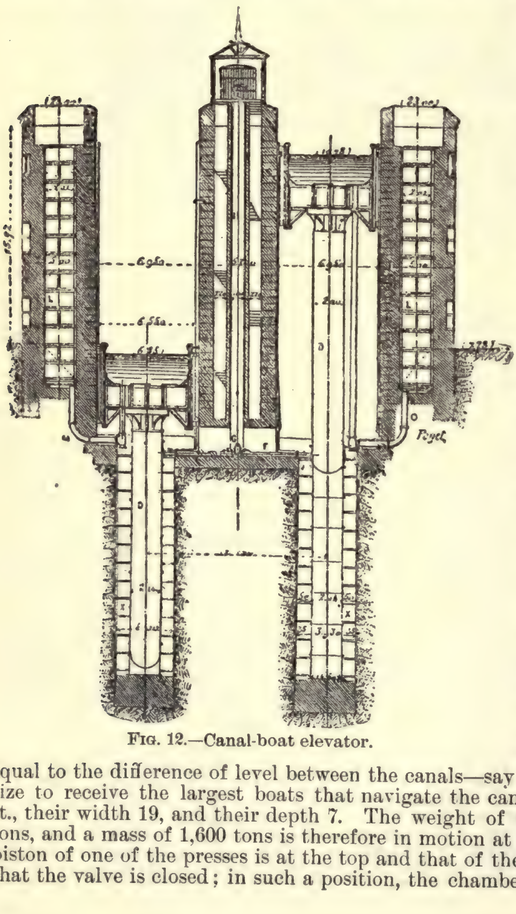


FIG. 12.—Canal-boat elevator.

IV. CANAL ELEVATORS.—The elevator for canal-boats at Les Fontenelles, near St. Omer, on the Neuffosse Canal, is the greatest hydraulic work ever undertaken in France. It is capable of lifting boats of 300 tons. Hitherto the largest canal elevator has been that constructed on the Trent and Mersey Canal in England, which lifts boats of 80 tons. The apparatus, as shown in Fig. 12, is essentially formed of two portions of a canal in plate-iron, called lock-chambers. Each of these rests at its center upon the head of a piston which works in the cylinder of a hydraulic press, placed in the center of a well. The two presses communicate through a pipe provided with a sliding valve, which permits of isolating or connecting them. When the valve is open, we have a true hydrostatic balance. If one of the chambers is more heavily loaded than the other, it descends, and forces the lighter one to ascend. Such is the apparatus as a whole. The stroke of the pistons is equal to the difference of level between the canals—say 43 ft. The chambers are of sufficient size to receive the largest boats that navigate the canals of the north. Their length is 130 ft., their width 19, and their depth 7. The weight of such a chamber, full of water, is 800 tons, and a mass of 1,600 tons is therefore in motion at every manœuvre. Let us suppose the piston of one of the presses is at the top and that of the other at the bottom of its travel, and that the valve is closed; in such a position, the chamber on the head of the piston that is out

of its press will be on a level with the upper canal, while the other will be on a level with the lower one. Let us introduce a boat into each of the chambers and close their gates and those of the canals, so as to isolate the chambers completely, and we shall not affect the equilibrium of the system, which will remain immovable. If, now, we open the sliding valve, the upper chamber will descend and the lower will rise, and this motion will proceed until the two chambers are on the same level. At this instant the two chambers will be at the center of their travel and in equilibrium upon their presses, which contain the same height of water. In order to force the chamber that was on a level with the upper reach to descend, instead of giving it the same quantity of water as is given the lower chamber, it is supercharged in the beginning with a weight of water equal to that contained in a press, so that, instead of stopping in the middle of its travel, it continues its motion until it reaches the level of the lower canal.

The presses are 55 ft. in height and 6½ ft. in diameter. They resist an internal pressure of 27 atmospheres. They are made of rolled steel rings, superposed and set into a groove, to prevent them from moving laterally. In order to render the interior of the press absolutely tight, it is lined with copper $\frac{1}{16}$ in. thick, in a single piece applied by a mallet against the sides. A section of one of these presses has supported an internal pressure of 175 atmospheres without distortion.

The largest canal lift in the world is at La Louviere, Belgium. The height to which the boats are raised is 50 ft. 6½ in. Two huge troughs, 141 ft. long by 19 ft. broad with 8 ft. draught of water, receive the boats, and are themselves carried on a ram 6 ft. 6¾ in. in diameter and 63 ft. 9½ in. long working in a cast-iron press. The pressure used is 470 lbs. per sq. in. Time of operation, 2 minutes.

Eliminator: see Separators, Steam.

Emery-Wheels: see Grinding Machines.

ENGINES, AIR. The air-engine described below, built by the Ticonderoga Machine Co., at Ticonderoga, N. Y., is based on the well-known Stirling principle, in which the working-air is confined to the machine, and originally compressed to a high pressure. Fig. 1 is a perspective view, and Fig. 2 is a sectional elevation. For the purpose of making its operation easily understood, Fig. 3 is introduced, which is a sketch of the simplest form of single-acting engines on the same principle.

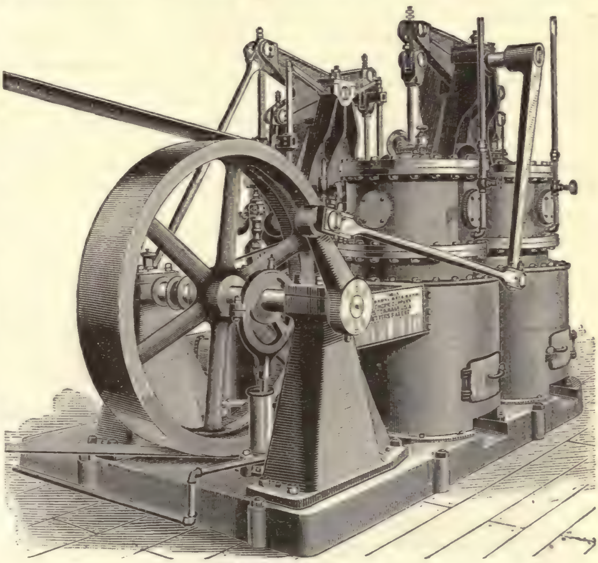


Fig. 1.—Air-engine.

A is the furnace, of simple and common form, with door, ash-pit, flue, and grate, on which a fire is built to heat the lower end of the reverser, which stands above the furnace. The bottom of the reverser-cylinder *B*, called the "heater," is made of special form, shown in Fig. 2, and of a special metal, and is arranged to be separately renewed. The top of the reverser is a common cylinder-head. The reverser consists of two cylinders, one within the other, and having the same vertical axis. The inner cylinder is fitted with a valveless piston having a piston-rod. This piston is moved by the engine, and does no work on its crank-arm. The inside cylinder of the reverser does not extend to the top or bottom of the outside cylinder, and has no heads, so that there is free communication from below the piston to the top at all times, no valves at any time intervening. It will be seen that by the upward stroke of the piston the air is forced by way of the annular space between the two cylinders to the bottom of the cylinder, and the downward stroke of the reverser-piston produces the reverse motion of the air to the top of the cylinder *via* the same annular space. The upper portion of this annular space is partitioned horizontally, and made into a water-jacketed condenser or cooler *F*, having vertical copper tubes surrounded by flowing water, the tubes allowing the air to pass freely through, as forced by the piston, without coming in contact with the water. The annular space *E E* below the cooler extending down into the heater, or lower end of the reverser-cylinder, is occupied by a regenerator of wire-screen cloth. When the air is moving upward, having just come from the hot surface *B*, on account of the air being warmer than the wire, the wire receives a portion of the heat of the air, and the air as it goes upward becomes cooled, first by the wire, then by the water-cooled pipes. The heat which the running water takes up is lost, but the heat in the regenerator is utilized in reheating the air on its return to the bot-

tom of the regenerator. These operations go on at each stroke of the piston. If the piston of the reverser is forced downward, the air in the reverser is cooled; if it is forced upward, the air is heated. It is found that it does not matter how quickly this stroke is made, or what the pressure of the air inside the reverser. When a fire is made and the heater properly heated, and the water running through the cooler, the air when at the lower end of the reverser is at 600° F.; and as the pressure is the same on the top and bottom of the reverser-piston at any instant, all the power required to move the piston is that necessary to overcome the friction of the air in the regenerator and cooler. Some of these engines have run 200 turns per min., so that the air is 200 times heated and 200 times cooled per min. The engine is designed upon the well-known principle that if a volume of air at any pressure is confined, and its volume not allowed to increase, while its temperature is increased 480°, the pressure will be doubled. On the temperature being decreased 480° again, the pressure decreases to the original pressure. It is found that but little more coal is required to keep up heat when using four atmospheres than in carrying one atmosphere-pressure in the reverser. The advantage of using the higher pressure is very great, notably in efficiency of engine, less bulk, weight, and cost of manufacture, and operation. As shown in Fig. 1, the reverser is connected by a pipe with a cylinder containing a working-piston, and the two pistons are connected by mechanism in such a way that the reverser-piston is 90° ahead of the working-piston, and makes a stroke for each stroke of the working-piston. This arrangement produces pressure in the working-cylinder varying between the pressure due to 120° F. temperature and that due to 600° F. temperature in the reverser. When the engine is started it is run on common air until a small pump which it carries compresses enough air into the engine, say 45 lbs. above atmosphere; from that time on this air-pump is only called on to supply whatever the leakage may be. An air-tank is connected with the engine, to store a small quantity of air for starting the engine when under load.

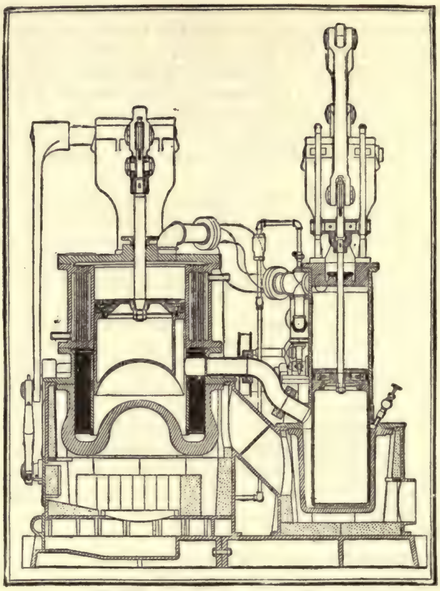


FIG. 2.—Air-engine—section.

The best results have been obtained from making the engine in the form shown in the perspective view—that is, with two reverser-cylinders and two double-acting working-cylinders. The reverser-pistons are connected and balanced by a walking-beam, as shown on the right, and are reciprocated by an overhanging side-lever, which is connected to the crank-arm by its connecting-rod. The working-pistons are connected by another walking-beam, and drive the engine by means of a connecting-rod joined to the third arm of the working-side walking-beam. A common ball-governor is used to actuate a by-pass valve, which when open tends to equalize the pressure on opposite sides of the piston, in that way regulating the speed of the engine. Instead of one outlet from the reversers to the working-cylinders there are two, and two for each of the working-cylinders. Each reverser is connected from the under side of the reverser-piston to the under side of the working-piston directly opposite by a pipe without valves, and the top of each reverser is connected with the top of the working-cylinder diagonally opposite by a suitable pipe: thus the pressure from each reverser is exerted on the lower side of the working-piston directly opposite and on top of the working-

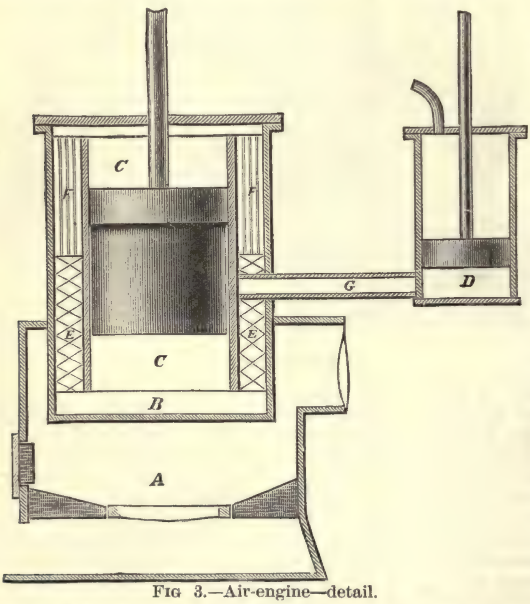


FIG 3.—Air-engine—detail.

piston diagonally opposite at the same time, at the proper moments, to produce motion to rotate the wheel. By this arrangement only cooled air comes in contact with the portion of

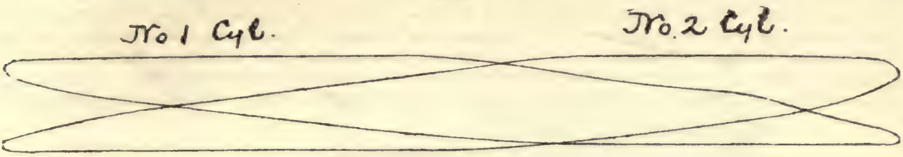


FIG. 4.—Air engine—indicator card.

the cylinder where the piston-rings slide, and with the piston-rods and boxes, so that there is no trouble in packing or lubricating.

In the perspective view the reversers are shown on the right with their two furnaces, the walking-beam connecting the two reverser pistons and the overhanging side-lever with its connecting-rod. These working parts are all driven by the crank, as shown. The working-cylinders on the opposite side are not visible in the picture, but their walking-beam and the piston-rods show their position. This walking-beam, as is seen, has a third arm, which is by a connecting-rod joined to the working-side crank-arm, which drives the shaft carrying the fly-wheel. The small air-pump is shown on the eccentric.

In a test of one of these engines, made in March, 1889, by George H. Barrus, the following results were obtained: The average indicated horse-power was 31·18, and the average brake horse-power 19·92. The amount of gas-house coke used in 10 hours' run, including the wood and coke required to start the fire, beginning with a cold engine, was 1·91 lbs. per indicated horse-power per hour, and 2·98 lbs. per brake horse-power per hour. On the same test, for a period of 6¼ hours, after the engine had attained its normal conditions of work, the quantity of coke consumed was 1·54 lbs. per indicated horse-power per hour, and 2·37 lbs. per brake horse-power per hour. The quantity of water which passed through the coolers amounted to an average of 3,612 lbs. per hour, which is equivalent to 7·2 gallons per min. This water was supplied at a temperature of 36°, and discharged at a temperature of 102·8°.

A test with George's Creek Cumberland coal gave a result of 1·62 lbs. of coal per indicated horse-power per hour, and 2·48 lbs. per brake horse-power per hour.

Fig. 4 shows a pair of diagrams taken during these tests. The line at the bottom is the line of atmospheric pressure. The scale of the diagram being 40 lbs. to the in., it is seen that the air is worked between the pressures of about 65 and 45 lbs. per sq. in. The mean effective pressure in No. 1 cylinder is 12·3 lbs., and in No. 2 cylinder 13 lbs.

ENGINES, BLOWING. No important improvement in type of blowing-engines used at blast-furnaces has been brought into use in this country in recent years, it having been generally considered that as the fuel used to drive these engines was the furnace-gas which would otherwise go to waste, attempts to economize this fuel were unnecessary. The combining of blast-furnaces with steel-works, however, by which arrangement surplus fuel-gas at the blast-furnace may be used to drive the rolling-mills and other machinery, is likely to lead ere long to the adoption in blowing-engines of those principles which have contributed to the economy of steam in other engines, such as compounding, the balancing of strains through the multiple cranks, instead of equalizing them in enormous fly-wheels, and increasing the speed of rotation. Two cylinder compound blowing-engines with cranks at 90° have already been built in England, but three cylinders with cranks at 120° would probably be a better arrangement. Much attention has been given to improvements of the air-valves of blowing-engines for blast-furnaces, in order to diminish the air leakage and the resistance to the flow of air through the valve passages, and at the same time to increase the rapidity of the action of the valves, so as to allow greater piston-speed of the engine. These improvements have generally taken the form of an increase in the number and a decrease in the size of the valves. The Weimer Machine Works, of Lebanon, Pa., builds blowing-engines with valves which are simply rectangular pieces of leather, about 7 by 2 in., stiffened by a metal plate. Each valve covers an opening of a slightly smaller size in a vertical iron grating forming the valve-seat, and is free to move to and from this grating at each reversal of the movement of the piston. Positive valves operated by links attached to some moving part of the engine have been introduced to a limited extent, but their merits have not yet been proved. The vertical type of engine is now generally used for blast-furnaces. Horizontal engines, however, are still in use for blowing Bessemer converters.

Reynolds's Double Vertical Blowing-Engine.—Fig. 1 represents a style of blowing-engine recently introduced by the E. P. Allis Co., of Milwaukee. The chief feature of novelty of these

engines lies in the construction of the frame. They are a pair of wrought-iron frame vertical engines with an air cylinder placed over each steam-cylinder; the air-piston of each air-cylinder is actuated by a piston-rod, which is attached to the steam-piston directly underneath. The Reynolds-Corliss valve-gear is used on both steam-cylinders; the air-cylinders being furnished with air-valves, conveniently arranged in chambers which are cast on each end of the cylinder and extend completely around it. The method of securing the valves in these chambers renders each one accessible and exposed to view when the engines are running. Any one of them can be removed and replaced by a new one at any time without dismounting the engine

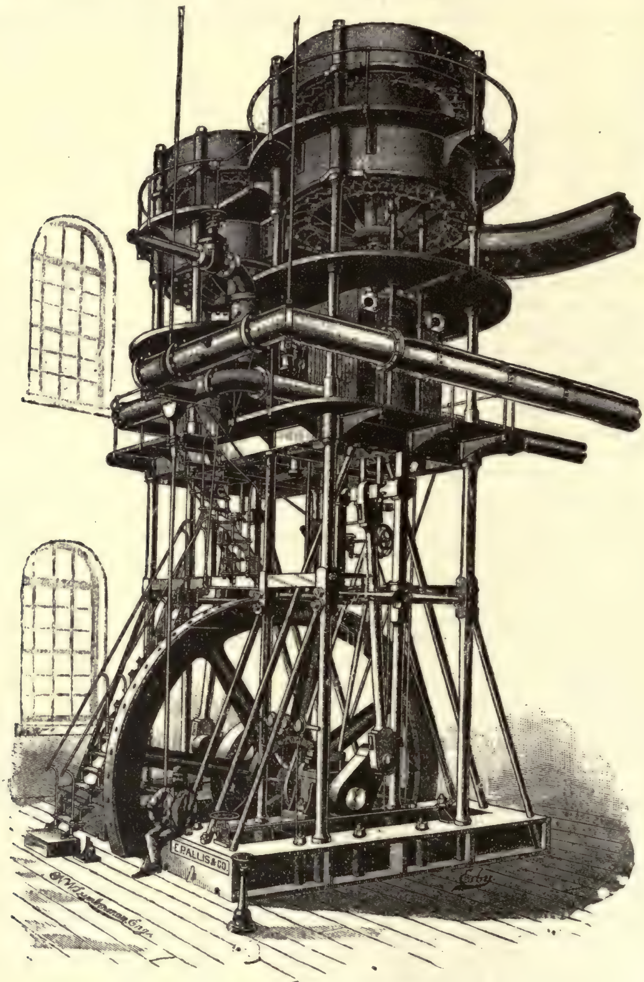


Fig. 1.—Allis blowing-engine.

or disturbing any other valve. The first pair of this type of blowing-engine was placed in the Bessemer department of the Joliet Steel Works, Joliet, Ill., in 1881.

See Air-Compressors. Blast-Furnace, Blowers, and Stoves, Hot-Blast.

ENGINES, FIRE, CHEMICAL. Apparatus for projecting a fire-extinguishing fluid. Two classes may be recognized:

I. Those which project a stream of water permeated with carbon dioxide, usually produced by the addition of an acid to a solution of soda carbonate.

II. Those which project a liquid which, when subjected to high temperature, will liberate a fire-extinguishing gas.

Each of these classes may be subdivided in portable and stationary machines.

The Babcock and many other well-known forms of "fire-extinguishers" belong to the first class above noted. As an improved example of a portable engine of notable capacity, the

Holloway Chemical Fire-Engine is here presented (Fig. 1). In this machine the principal improvements are in constructive detail. The tanks (double) are of heavy polished copper, and are bolted on wrought-iron frames, and braced one to the other. The hose-gallery and

automatic reel are carried over the frame-arch. The acid-chamber is lined with glass, and is supported above and outside of the tanks. In the tanks are agitators turned by handles on the outside, the purpose of which is thoroughly to dissolve the soda.

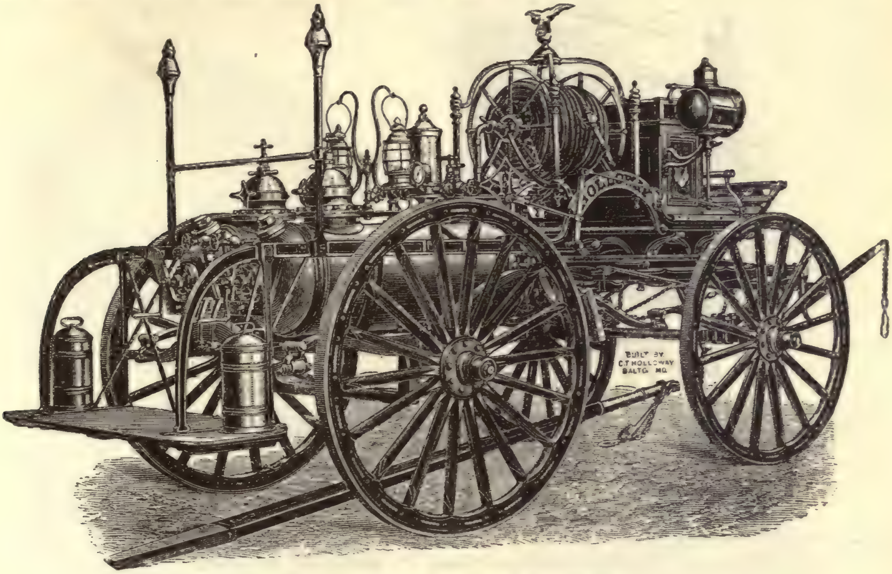


FIG. 1.—Holloway chemical fire-engine.

The discharge-pipes on the tanks are very short and without bends, allowing the free and unresisted passage of the solution from the tank to the hose. The double-tank engines are arranged to give a continuous stream without moving the hose. While one tank is being discharged the other is replenished, and so on, or both tanks can be discharged simultaneously, thus playing two streams. An automatic hose-reel is connected to the tanks by a short pipe, and the hose is attached to it. By the use of this reel the hose is always ready for instant service, as the solution passes from the tank into the reel and through the hose. It is only necessary to draw off the required length of hose to reach the fire, the balance remaining on the reel, thus obviating the delay of unreeling the hose and making connections to the tanks. A pressure-gauge shows the amount of gas generated within the tank, and also enables the person operating the engine to determine how fast the tank is being emptied.

A stationary apparatus of the same general type is represented in Fig. 2. The receptacle for the chemicals and water is located in the cellar of the building, and supported on an axis in a suitable frame, so that it can easily be rotated to produce intermingling of the gas-forming substances. Communicating with the receptacles are stationary pipes leading to various parts of the building, and provided with hose. The pressure of the generated gas forces the mingled gas and water through the pipe-system.

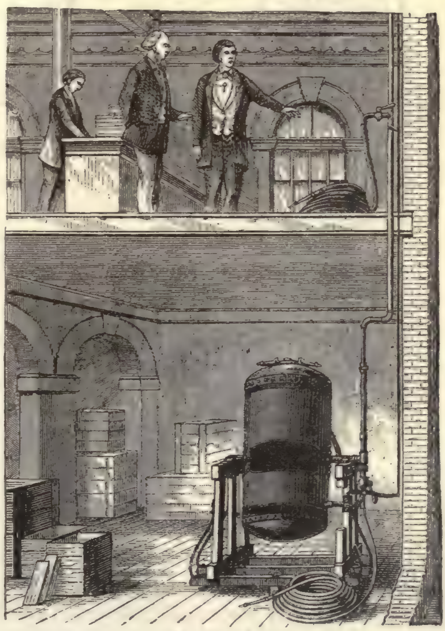


FIG. 2.—Stationary chemical fire-engine.

An example of a chemical-engine of the second class is given in Fig. 2, which represents the

Lindgren-Mahan Chemical Fire-Engine (Fig. 3), here shown as a light, easily drawn vehicle for town or village use. In this apparatus there is used a fire-extinguishing fluid, which is claimed to liberate an "oxygen-destroying gas" on coming in contact with the fire, the effect of 1 gallon of which is "equal to that of 800 gallons of water." The principle of

the operation of the machine will readily be understood from Fig. 4, which represents a portable fire-extinguisher. The receptacle is filled with the solution, and with strongly compressed air, by means of which the liquid is projected. In the large engine the receptacle

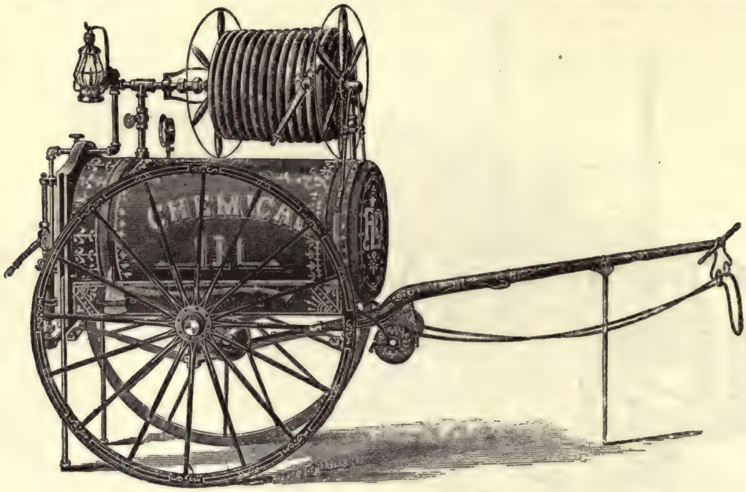


FIG. 3.—Lindgren-Mahan chemical fire-engine.

used is a steel cylinder, into which air is forced at a pressure of 100 lbs. per sq. in. Pumps are provided for re-establishing the pressure and for filling the cylinder.

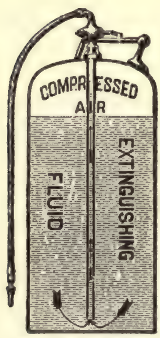


FIG. 4.—Portable fire-extinguisher.

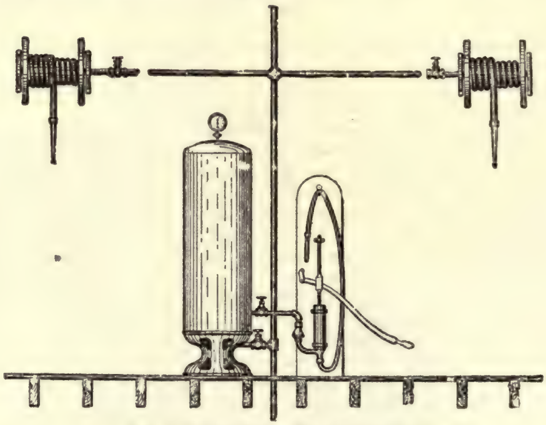


FIG. 5.—Stationary fire-extinguisher.

Fig. 5 represents the stationary form of engine of this type. The fluid is forced through the pipe-system by the air-pressure, so that there is always a steady pressure on the hose-valves. By opening these, streams of fire-destroying fluid may at once be obtained.

ENGINES, FIRE, STEAM. *The Clapp & Jones Steam Fire-Engine,* manufactured by the Clapp & Jones Manufacturing Co., of Hudson, N. Y., is illustrated in Figs. 1 and 2. This is a piston-engine presenting many points of novelty and interest. Sectional views of the boiler are given in Figs. 1 and 2, Fig. 1 being a vertical section through the center.

Fig. 2 is a sectional cut on a horizontal line, one half being through the steam-chambers; the other half is through the fire-box, just below the lower tube-sheet.

Like letters on both cuts refer to the same parts: *a a* is the outside shell, which extends the whole length of the boiler; *b b* is the fire-box sheet, which is less in length, it going only to the lower tube-sheet; *c* is the lower tube-sheet, showing all the tube-holes; the heavy-line circles show which are used for the coil-tubes in the fire-box; the others are for the smoke-tubes; *d* is the upper tube-sheet, which has holes only for the smoke-tubes; *e e e* are the smoke or draft tubes, which also answer another very important purpose—that of drying and superheating the steam. These are usually made of copper or iron. *F F F* are the sectional coil-tubes, the main feature of this boiler. They are in the form of a spiral coil, the spiral bend being enough to leave room for five others of the same size between, so that there are six of these coils in each circular row. The number of rows is determined by the size of the boiler and the amount of steam required. *G G* is the ornamental dome; *g g* is the smoke-

bonnet and pipes for concentrating the hot escaping products of combustion for the purpose of making a draft of air through the fuel. At *H* are the grate-bars, *I* the flue-door, and *J J* is the water-line.

The arrows marked *K* show the direction of the circulation when working with the fire in the fire-box; those marked *L* show the direction of it when on the heater, which is directly opposite. The outside pipe connected at about the water-line is the outlet from the heater, and the inlet to the boiler, which carries the heated water over the crown-sheet, where, as it gets cooler, it enters the coils and then the leg, and from there to the pipe near the bottom of the boiler. The pipe leads to the heater, so that the water is kept moving just in proportion to the heat given it. Any kind of a heater can be used with the same result. *M* shows the pipe and valve that brings the hot water from the heater. *N* is the pipe and valve that leads from the boiler to the heater. The valve in *M* is a stop and check combined. The pipe in *N* has a trip-valve that is worked by hand or made automatic, as desired.

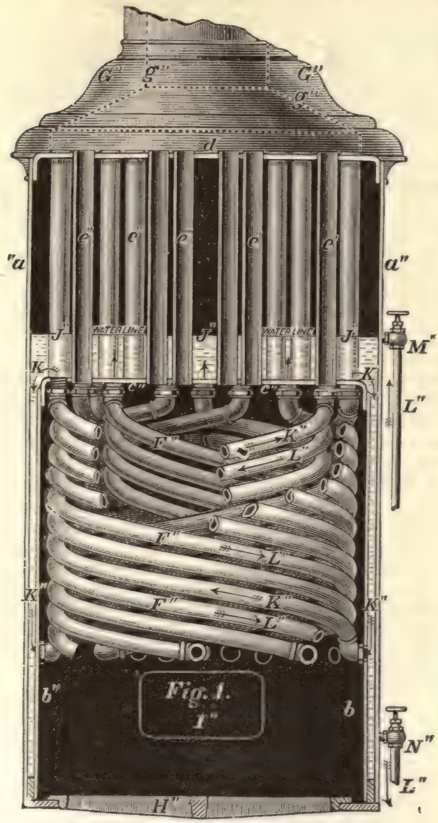


Fig. 1.—Steam fire-engine boiler.

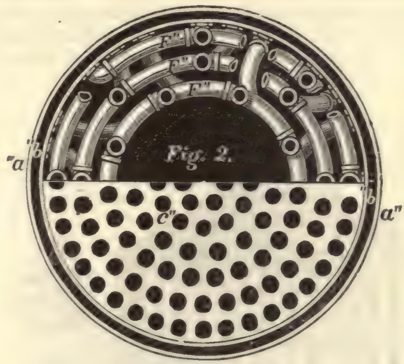


Fig. 2.—Boiler section.

We illustrate in Fig. 3 one form of Clapp & Jones engine, known as a village engine, or No. 5. It is made direct-acting, without crank or fly-wheels, and is claimed to be the lightest double engine made. Its weight is but 4,000 lbs., and capacity 400 gallons per min. The dimensions are as follows: Steam-cylinders, 7 in × 7 in. stroke; pumps, 4⅝ in. × 7 in. stroke; number of streams, from 1 to 3; length, 10 ft. 4 in., including horse-pole, 21 ft.—with hand-pole, 16 ft. 4 in.; height, 8 ft. 5½ in.; extreme width with hand-pole, 5 ft. 7 in.—with horse-pole, 6 ft. 6 in. This engine will throw a 1½-in. stream from 230 to 260 ft.

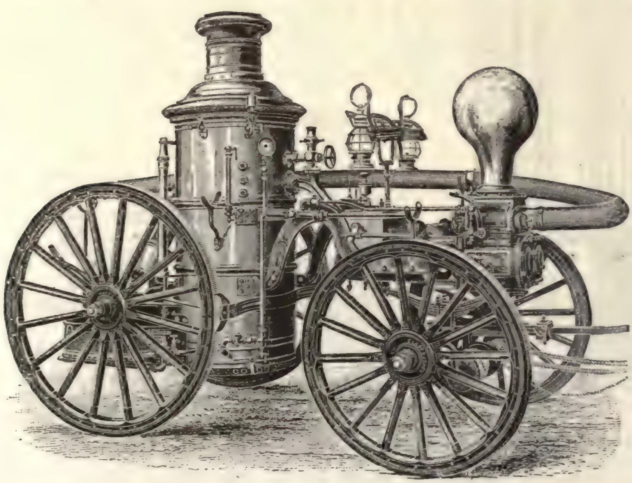


Fig. 3.—Fire-engine.

The pumps in these engines are of copper and tin, to avoid corrosion, and have a frictionless metal plunger, requiring no packing and rubber valves. From a number of reports of tests submitted by the manufacturers, the following are

selected. Trial at Washington, D. C., Nov. 15, 1889, of a second-class double-working engine at the river-front in the United States Navy-Yard:

Test.	Line of hose laid.	Nozzles.	Steam.	Water.	Distance.
1......	Two 50-ft. sections $2\frac{1}{2}$-in. hose, Siamese into 25 ft. 3-in. hose........	$1\frac{1}{2}$ in.	165	165	262
2......	Same line........	$1\frac{1}{2}$ in.	160	160	283 ft. 3 in.
3......	" "	$1\frac{3}{4}$ in.	140	135	236 ft. 9 in.
4......	" "	2 in.	180	110	218 ft. 8 in.
5......	Two 50 ft. sections $2\frac{1}{2}$-in. hose, Siamese into 50 ft. $2\frac{1}{2}$-in. hose........	$1\frac{3}{8}$ in.	155	215	256 ft. 7 in.
6......	Two lines 100 ft., each $2\frac{1}{2}$-in. hose........	Two $1\frac{1}{8}$ in.	170	150	256
7......	Three lines 100 ft., each $2\frac{1}{2}$-in. hose........	One $1\frac{1}{4}$ in. Two 1 in.	165	115	215 ft. 4 in.
8......	Three 50-ft. sections $2\frac{1}{2}$-in. hose, Siamese into 25 ft. 3-in. hose........	$1\frac{1}{2}$ in.	160	155	Vertical, 136
9......	Same line........	$1\frac{3}{4}$ in.	170	120	235 ft. 3 in.
13......	" "	2 in.	165	100	218
14......	" "	$1\frac{1}{2}$ in.	160	155	288 ft. 8 in.
10......	500 ft. $2\frac{1}{2}$-in. hose........	$1\frac{1}{8}$ in.	135	230	218
11......	500 ft. $2\frac{1}{2}$-in. hose........	$1\frac{1}{4}$ in.	150	255	231
12......	Three 50-ft. sections $2\frac{1}{2}$-in. hose, Siamese into 25 ft. 3-in. hose........	$1\frac{3}{8}$ in.	170	175	224 ft. 10 in.

The needle on steam-gauge moved in $2\frac{1}{4}$ min. after lighting fire: 5 lbs. steam in $3\frac{1}{4}$ min.; 10 lbs. steam in 4 min.; 15 lbs. steam in $4\frac{1}{2}$ min.; 25 lbs. steam in 5 min.; 30 lbs. steam in 6 min., when engine started, taking suction from river. The following is of interest as showing the performance of the engine under conditions of actual use. The occasion was a large fire in a saw-mill at Portland, Oregon. The engineer in charge of the machine reports: "We were called in service on Friday morning, July 25, 1890, at 11 o'clock, and the engine was run steady, with three streams attached, the steam registering 100 to 110 lbs., and the water-pressure from 90 to 100 lbs., until Saturday, Aug. 2, 1890, at 10 o'clock A. M., thus making a total of 191 hours, or 1 hour less than 8 days. This was not all: the water was forced up an inclined bank through 2,400 ft. of hose, two lines of 750 ft., and one line of 900 ft., and the nozzle-tips were as follows: 1 of $1\frac{3}{8}$ in.; 1 of $1\frac{1}{4}$ in.; and 1 of 1 in. The average revolutions were 270 per min. The engine worked smoothly and regularly."

The La France Steam Fire-Engine, made by the La France Fire-Engine Co., of Elmira, N. Y., is represented in Figs. 4, 5, 6, 7, and 8. This is a piston-engine of novel and improved construction; the boiler being a special feature of importance. Fig. 4 is a vertical section of the entire apparatus. Fig. 5 is a sectional view of a cluster or "nest" of water-tubes, comprising 9 $1\frac{1}{4}$-in. tubes, connected by right and left threads to malleable-iron "headers." Fig. 6 is a view of the water "header" at top of Fig. 5, which screws into the crown-sheet. Fig. 7 is a view of the "water-ring" at bottom of Fig. 5, which connects with leg of boiler. The crown-sheet L is placed below the top of

Fig. 4.

Fig. 6.

Fig. 7.

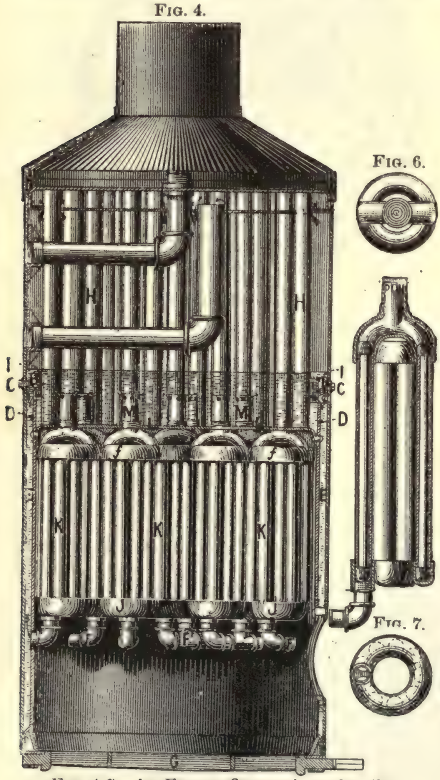


Fig. 4-7.—La France fire-engine—details.

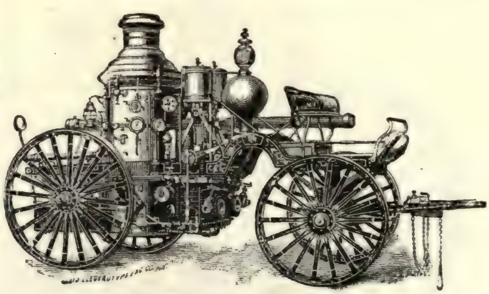


Fig. 8.—La France steam fire-engine.

the fire-box sheet, as shown at D. The "water-nests" are suspended in the fire-box, as at K. The top "header" J is screwed through the crown-sheet, and so arranged that the lateral discharge-openings are 3 in. above the crown-sheet, as shown at M. The bottom "water-rings" are each connected with the bottom of the boiler by means of nipples and elbows, as shown at

F. By this arrangement a great extent of water-surface is exposed to the heat without obstructing the smoke-flues or weakening the crown-sheet with numerous openings. The smoke-flues *A* are arranged to encircle the "nest-headers," making a direct draft for the flame through the "nest." They pass directly through the boiler to the stack above, passing near the top of the boiler through the diaphragm-sheet *A*. The openings in this sheet are slightly larger than the smoke-flues, leaving an annular space through which the steam passes to the space above, that serves as a steam-drain, whence the steam-pipe carries it to the engine. This causes the steam to pass in films in contact with the hot flues, at once superheating the steam and keeping the tops of the flues in the moisture, preventing burning and leaking. Above the crown-sheet a ring *I*, of L-shaped cross-section, is attached to the inner surface of the boiler-shell, forming a receptacle *B* for mud and other impurities in the water, which are carried upward by the natural circulation of the water. Mud-plugs are provided for cleaning and washing the space *B*.

The circulation, as shown by the arrows, is down the "leg" *E*, and up through the "nests" *K*, discharging steam and water laterally from the openings over the crown-sheet *L*. By this means the crown-sheet is always protected by a pan of water formed by the extended edges of the fire-box sheet *D*, and can not be injured, whether the water-line is carried above or below the sheet, so long as enough water remains in the "leg" *E* to supply the "nests."

The following are the results of a series of official tests (competitive) of a second-class La France engine, made by the Philadelphia Fire Department in April, 1886: Height of engine over all, 9 ft. 6 in.; length over all, 24 ft. 6 in.; width over all, 6 ft.; weight without supplies, about 6,700 lbs. Running 1½ hours with 50 ft. of hose, 1¼-in. nozzle, average steam-pressure, 109¾ lbs., average water-pressure, 175¼ lbs.; running 30 min. with 400 ft. of hose, 1¼-in. nozzle, average steam-pressure, 124⅙ lbs., average water-pressure, 260 lbs.; running 25 min. with 400 ft. of hose, 1½-in. nozzle, average steam-pressure, 125 lbs., average water-pressure, 275 lbs.: total running time, 2 hours 25 min. Consumption of coal, 1,446 lbs., an average of 598$\frac{10}{29}$ lbs. per hour.

The following shows the steam-making and water-throwing capacity of an engine of this type, as determined hy experiments at Chester, Pa., in 1887:

Steam-pressure after 1 min.	2⅓ lbs.
" " " 4 "	38 "
" " " 6½ "	120 "

Horizontal distance of stream thrown with 1¼-in. nozzle and 100 ft. of hose on each coupling, 265 ft.; with 1⅜-in. nozzle, same amount of hose, 308 ft.; with 1⅝-in. nozzle, 312 ft.; with 1¼-in. nozzle and two separate streams, through 500 ft. of hose each, 235 ft.

The Button Steam Fire-Engine, represented in Fig. 9, has an upright tubular boiler with copper flues, which are so arranged as to be always covered with water at whatever inclination the engine is worked. Plunger-pumps are employed, which are cast in a single piece without packed partitions. All the movable parts of the engine are reciprocating. The manufacturers claim that a double-pump engine having pumps 6 in. diameter by 4½ in. stroke throws precisely the same quantity at each revolution as an ordinary double-pump engine with pumps 4½ in. diameter by 8-in. stroke. "The travel of the pistons in such an engine is 32 in., while in the Bulton it is but 18 in., and the sq. in. of frictional surface are 1,218, as against 819 in. to do precisely the same work." These arrangements, it is claimed, produce a double-plunger engine, which operates with minimum friction, while it discharges a continuous stream like a fountain or hydrant, and has no dead center or point at which the steam will not start it.

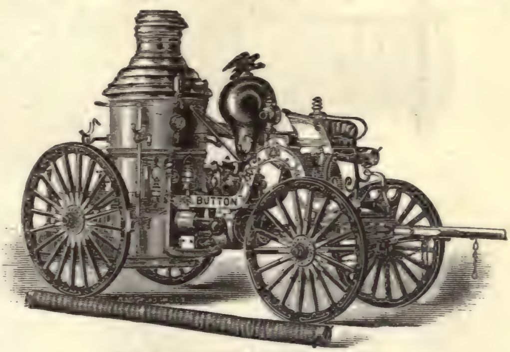


FIG. 9.—Button steam fire-engine.

The following shows the results of a recent test of the third-size Bulton engine at Akron, Ohio: Weight of machine, 5.800 lbs.; steam-pressure, after 2½ min., starting with cold water, 5 lbs.; after 6 min., 40 lbs. With a steam-pressure of 130 lbs., and a water-pressure of 228 lbs., water was lifted 13½ ft. With a 1¼-in. nozzle water was thrown horizontally 292 ft.

The Ahrens Steam Fire-Engine, manufactured by the Ahrens Manufacturing Co., of Cincinnati, Ohio, is illustrated in Fig. 10. The principal feature of this engine is its boiler, which is represented in the sectional views, Figs. 11, 12, 13. This has a steam and water-space, which forms the fire-box, and inside of which is fastened a coil, through which the water is forced—a circulating pump being especially provided for this purpose. The water enters the coil at *D*, and is converted into steam while traversing the pipes *F F*, and finally the mingled steam and water passes back to the boiler at *A*. The coil is supported by the slats *B*. By removing the bolts out of slats *B B*, breaking joints top and bottom, any or all sections of coil can be removed, should any repairs be necessary, and any or all may be re-

placed in a few hours. The water, in entering at D, is separated into two parts, and then into four parts, by a patent device inserted in the dividers at the bottom, so that each section gets its equal amount of water in proportion to the number of feet of pipe in the section. At

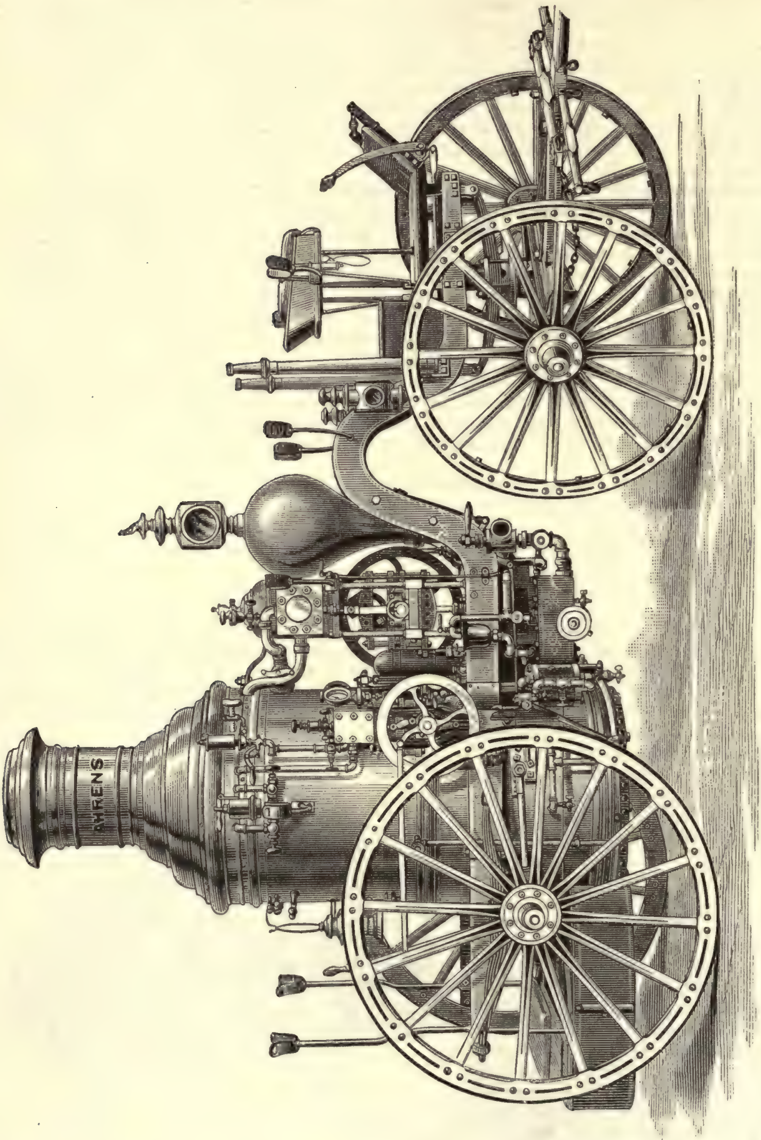


Fig. 10.—Ahrens steam fire-engine.

E are the grate-bars, and at W the water-line. The makers claim that from 31 to 40 gallons of water can be carried without interfering with the generation of steam, that steam can be generated as readily with 38 gallons of water as with 30 gallons, and that in sufficient quantity for the engine to throw water from a nozzle in 4 min. from the time of lighting the fire.

The Amoskeag Steam Fire-Engine has an upright tubular boiler and a double-acting and vertical piston-pump. The following results of tests of a first-size engine of this type are given by the manufacturers, as determined at Syracuse, N. Y., in August, 1885: Height of engine over all, 9 ft. 1 in.; length over all, 24 ft. 2 in.; width over all, 6 ft.; weight without supplies, about 8,000 lbs.; capacity, 900 gallons per min. Horizontal streams were thrown through smooth-bore nozzles as follows: $1\frac{1}{4}$-in. nozzle, 334 ft.; $1\frac{1}{2}$-in. nozzle, 334 ft.; $1\frac{3}{8}$-in. nozzle, 329 ft.; $1\frac{5}{8}$-in. nozzle, 316 ft.; two streams, $1\frac{1}{8}$-in. nozzles, 296 ft.

The Silsby Steam Fire-Engine (Fig. 14).—It is claimed for this engine that there is an

entire absence of valves, connecting-rods, eccentrics, cross-heads, cranks, balance-wheels, packing-plates, and other complicated parts, and that the machine stands still while running even at its greatest speed. The motion of the pump being equable, continuous, and rotary, no blows are given to the water, which enters and leaves in one steady flow, and there is no irregular motion to the stream.

The boiler is vertical and cylindrical; from the crown-sheet depend water-tubes having in them concentric circulation-tubes, causing in each tube a strong central downward current of water, which, mostly converted into steam, ascends in a thin film in the annular space between the outer tube and the inner or circulation tube. These drop-tubes are ranged in concentric circles, those in the outside rows being longer than the others, thus better utilizing the space in the combustion-chamber. The gases of combustion pass from the combustion-chamber or furnace through vertical smoke-flues set concentrically, a conical smoke-chamber, properly jacketed, connecting with the stack; and the draft being regulated by a variable exhaust-nozzle, from which the rapid succession of discharges makes, in effect, a steady blast, which does not "pull fire," and thus endanger neighboring property. This variable exhaust-nozzle has several outlets, each controlled by a conical plug, all of which are regulated at once by a suitable lever.

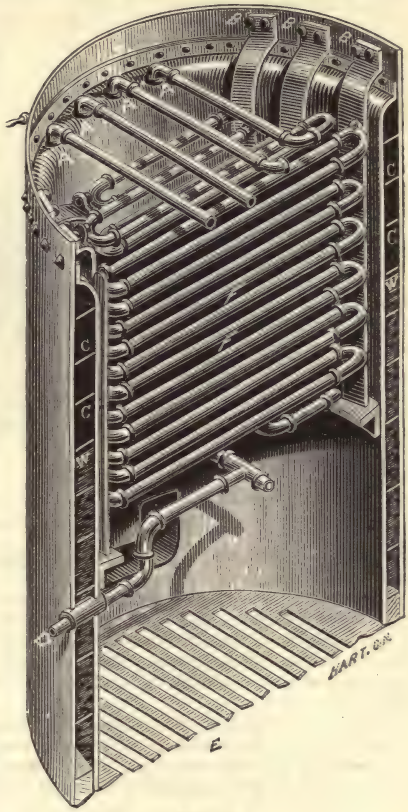


Fig. 11.

The shell and fire-box are of tough steel, having a tensile strength of 60,000 lbs. to the sq. in. The water-tubes are inclined outward at the bottom, so as to assist the draft and to present the tube-heating surface to the best advantage. They are screwed into the crown-sheet, and the circulation-tubes have at their lower ends triangular casements, to prevent the lifting of the water by the rapid circulation. The steam made in the outer annular passages in the drop-tubes and elsewhere is dried and further heated by the smoke-flues passing through the steam-chamber. The steam is taken from a circular perforated dry pipe running around the steam-space of the boiler. The water-level is carried about one third way up in the steam-chamber.

It is claimed that this boiler will raise steam from cold water in four to six minutes, will burn coal or wood, will not foam nor prime, and will use salt water if necessary.

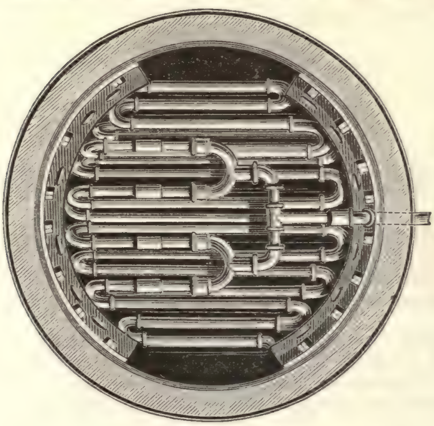


Fig. 12.

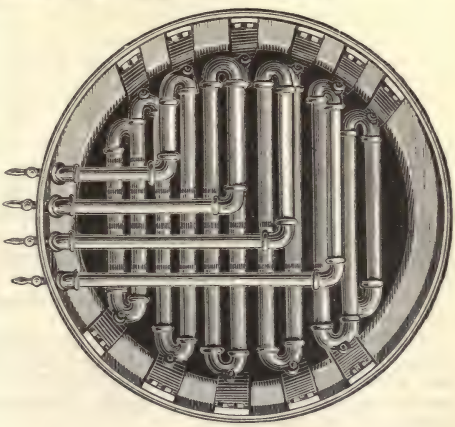


Fig. 13.

Figs. 11-13.—Ahrens fire-engine—sectional details.

The engine contains two rotating pistons or cams, both alike, and each of which is in effect a gear-wheel having eight short teeth arranged in pairs, with one long tooth and one deep space between each two pairs of short teeth. The short teeth are for the purpose of insuring that the two cams rotate exactly together. The long teeth are in effect abutments for

the steam, forming as they do steam-tight joints with the walls of the case in which they rotate, and with the deep spaces in which they engage. The steam, entering at the bottom of

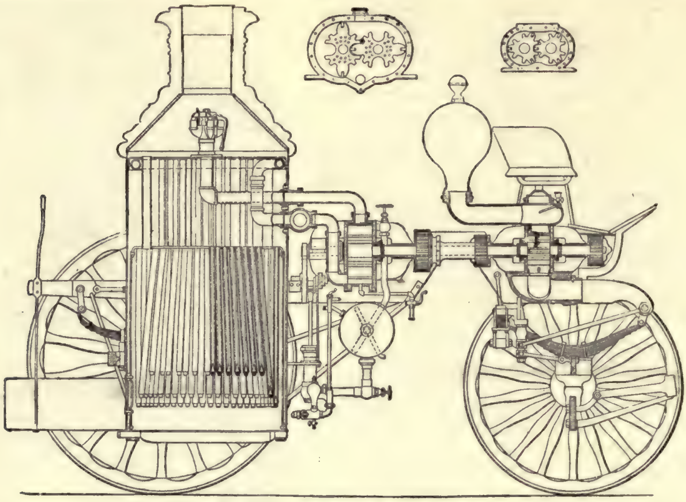


FIG. 14.—Silsby steam fire-engine.

the case, tends to press the abutments apart, and thus cause rotation of the pistons in opposite directions.

The construction of the pump is upon the same general principle as that of the engine, only there are three long teeth to each cam, and fewer short or guide-teeth. The water enters at the bottom of the case by the suction-opening, and is discharged at the top by the outlet. The revolution of the pump-pistons in opposite directions causes a vacuum in the case, and the water rushes up to fill it, and is then caught by the long teeth or abutments and swept out of the case.

The main pump, if the engine is to be used in connection with water-works, has a churn-valve by which the stream may be led from a hydrant through the suction-hose into the discharge-hose, without revolving the pump or any portion of the machinery.

The following is a record of trials at Cedarville, Ohio, of a

No. 5 Silsby Engine, March 31, 1888.

Test No. 1—engine started in 6 min.

Test.	Number of streams.	Hose, feet, each line.	Nozzles, inches.	Horizontal distance.
2	1	100	$1\frac{1}{4}$	272 ft.
3	1	100	$1\frac{1}{8}$	283 ft.
4	1	50 siamesed	$1\frac{5}{8}$	295 ft.
5	2	100	$\frac{3}{4}$	215 ft.
6	3	100	$\frac{5}{8}$	197 ft.
7	1	800	1	200 ft.
8*	1	800	1	167 ft.

FIRE-BOATS.—The latest type of floating steam fire-engine is illustrated in Fig. 15. This is the boat New-Yorker, built for and in use by the Fire Department, and serving to protect vessels at the city piers and property on the water-front.

The boat and machinery are built of iron and steel throughout, under full specifications furnished by the department. The length over all is 125 ft. 5 in.; on load water-line, 115 ft. The beam molded is 26 ft.; on load water-line, 25 ft. 2 in. The depth molded is 14 ft. 6 in., and the extreme draft is 10 ft. The displacement is 351 tons. At the load water-line the displacement is 52 tons to the inch.

The boilers, two in number, are of the "Scotch" type, cylindrical, with corrugated furnaces. They are built for a working-pressure of 148 lbs. Each is 12 ft. diameter and 15 ft. long, with 204 tubes of $3\frac{1}{4}$ in. outside diameter. The outside sheets are $\frac{11}{16}$ in. thick, and other portions of reduced thickness. Artificial draft is provided, and the boilers can be worked together or independently.

The propelling-engine is of the triple-expansion direct inverted type, 24 in. stroke, with 15, 24, and 39 in. cylinders. The high-pressure cylinder has a piston-valve, the others have slide-valves. It can work up to 135 revolutions per min., with 135 to 150 lbs. boiler-pressure. The propellers are two in number. The fixed or forward screw is 7 ft. 9 in. diameter by 12 ft.

* In test No. 8 water was drafted 27 ft. and forced up an elevation.

pitch. Back of this comes the "Kunstadter" swiveling-screw and gear. This is connected by a universal joint to the shaft, which joint comes in line with the axis of rotation of the rudder. Thus the screw is swung to right or left with the rudder, and aids in manœuvring the boat. It has been found highly efficient. One independent air-pump and a circulating pump for

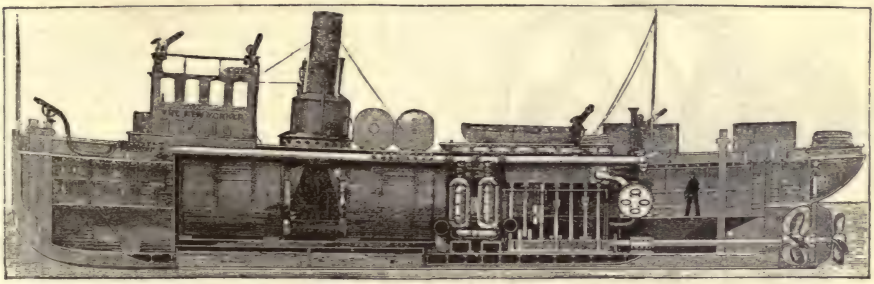


FIG. 15.—Fire-boat New-Yorker.

the condenser are provided. The condenser is of the tubular pattern, with about 2,000 sq. ft. of condensing surface. Steam-steering gear and engine are provided in addition to the regular hand-steering apparatus. For signaling, a steam-chime whistle and a steam calliope are provided.

The pumping-machinery is of great power. It comprises two duplex vertical direct-acting pumps. Each has two steam and two water cylinders. The steam-cylinders are 16 in. diameter by 11 in. stroke. The water-cylinders of the same stroke are of 10 in. diameter. The working pressure allowed for the water-cylinder is 200 lbs. to the sq. in. The pumps draw water in through two 16-in. suction-openings in the bottom of the vessel, to which suction-pipes are connected. The discharge is delivered through 9½-in. connections into a 12-in. main, that runs around the trunk or deck-house, and which is provided with numerous connections for hose-couplings. Several 12-in. valves are placed in the circuit, so as to shut off any desired portion. The line is provided with a number of 3½ and 6 in. hose-couplings. Four 7-in. hand-pipes are also carried upward, two to the roof of the pilot-house and two aft through the trunk. These are surmounted by swivel-nozzles, adapted for throwing 5½-in. streams if desired. A fifth swivel-nozzle is mounted on the bitts forward, and is joined by hose with one of the large connections. Altogether 32 discharges are provided for. The hand-pipes are manipulated from behind traveling-screens, made of double sheet-steel with 1-in. air-space, perforated for hose-pipes, and with peep-holes. These can be moved fore and aft to any desired point along the rail, and protect the firemen. There are three of these on each side. They are carried on rollers, which work upon the rail and upon the plank-sheer with guides. Any screen can be lifted off its bearings and carried to the other side of the deck. Movable fire-screens are provided for windows, which screens are kept stored away when not in use. Those for the pilot-house windows have peep-holes. As an additional protection four spray-pipes are carried up along the front of the pilot-house and elsewhere, with cap and hose connection at the top. The object of these is to distribute water in a spray or rain-like form over the deck of the boat. In this way the hose is protected in situations where the heat is great. Upon the trunk-deck are two swiveling hose-reels, on which the hose is kept. Of this there are 3,000 ft., ranging in size from 2½ in. to 6 in. diameter. A great variety of nozzles or discharge-pipes are provided, of about every size, from 2½ in. up to 5½ in. diameter. The capacity of discharge is put at 10,000 gallons per min., with the pumps making 200 revolutions.

The hull was built by Jonson & Ellison, of this city; the engines by Brown & Miller, of Jersey City, N. J.; the boilers by McNeil & McLoughlin, of Brooklyn, N. Y. One set of pumps was built by the La France Fire-Engine Co., of Elmira, N. Y.; the other by the Clapp & Jones Manufacturing Co., of Hudson, N. Y. The total cost is put at $100.000.

The following table shows the results of test made on the fire-boat Geyser, built for the city of Chicago by the Clapp & Jones Manufacturing Co. The figures in brackets indicate whether one or both pumps were worked, and [s] starboard pump, [p] port-pump:

	Steam pressure.	Water pressure.	Stream thrown.		Steam pressure.	Water pressure.	Stream thrown.
	Lbs.	Lbs.	Ft.		Lbs.	Lbs.	Ft.
One 4-in. [2]	85	80	396	One 3-in., Three 2-in. [2]	90	80	260 / 255
One 2½-in. [2]	82	120	431	One 3-in., Two 2-in. [2]	90	90	297 / 285
Two 2-in. [s]	95	150	340	Two 3-in. [2]	90	75	279
Three 2-in. [s]	95	95	287	One 3-in. [2]	95	130	325
Four 2-in. [s]	100	80	249	Two 2½-in. [2]	90	85	260
Two 2-in. [p]	95	140	340	One 2½-in. [2]	85	120	325
Three 2-in. [p]	95	90	283	Fourteen 1¼-in. [2]	85	65	204
Four 2-in. [p]	95	55	221				
One 3-in., Four 2-in. [2]	75	59	234 / 220				

The last performance, throwing 14 streams simultaneously 204 ft., was considered little short of marvelous.

ENGINES, GAS AND OIL. Gas-engines are now commonly used with a producer gas, made on a continuous process by air and steam being passed through incandescent coal. From the generator it is taken to the scrubber for the purpose of cleaning and cooling, and it is thence allowed to enter a small holder. From this the gas-engine draws its supply, and in case the production of gas exceeds the consumption, the holder filling and moving to its upper position will strike a stop, by which supply of steam and air is cut off from the generator, and the making of gas suspended until the drop of the holder causes it to be resumed again. In a test made by Prof. K. Teichmann, of Stuttgart, of a twin-cylinder Otto engine worked with producer gas, the engine developed a brake-power of about 52 horse-power, and the total fuel consumption, including that used for the superheating boiler, was 1·6 lb. per brake, or barely 1·3 lb. per indicated horse-power per hour. A still better result is reported in English tests—in Robinson's "Gas and Petroleum Engines"—which says that tests with an Otto engine, using Dowson gas, and indicating about 32 horse-power, have shown that the total fuel consumption, including that used for the production of superheated steam in the gas producer and for getting up fires at starting of the Dowson generator, was 1·2 lb. per indicated horse-power per hour. With a large twin-engine of 100 horse-power only 1·1 lb. of coal was required. The Otto gas-engine is fully described on p. 632, vol. i, of this work. It is represented in its most recent forms—horizontal and vertical—in Figs. 1 and 2.

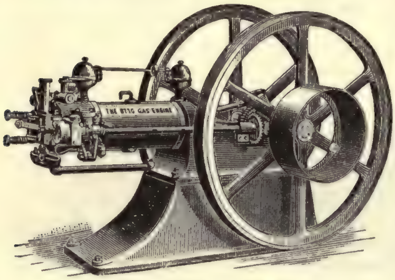


FIG. 1.—Otto gas-engine.

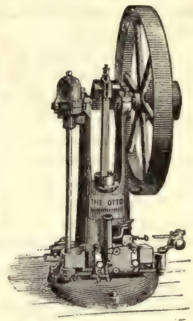


FIG. 2.—Otto gas-engine.

The Rollason Gas-Engine, made by the Electric Manufacturing and Gas-Engine Co., Greenbush, N. Y., is of the three-cycle type—i. e., the crank-shaft makes three revolutions for each explosion of gas, and the governor acts to regulate the amount of gas supplied for each explosion, from the maximum down to a point at which it can no longer be used economically, when the supply is cut off entirely, and no explosion takes place until a sufficient diminution of speed occurs.

The operation of the engine is as follows: Supposing an explosion to have just taken place, the piston, under the impetus given, makes a forward stroke; the exhaust-valve is then opened and the piston returns, expelling the larger portion of the products of combustion. During the next forward stroke a scavenger charge of air is drawn into the cylinder, and on return stroke is forced out through the exhaust, thus entirely clearing the cylinder and explosion-chamber. On the fifth stroke a combustible charge of gas and air is drawn in, compressed ready for ignition by the sixth or return stroke; thus the cycle is completed. At the commencement of the seventh stroke an explosion again takes place, and so on. The construction of this engine is shown in Figs. 3 and 4. The connecting-rod is pivoted directly to the piston, which has a guiding trunk. The cylinder is surrounded with a water jacket, which extends around the combustion-chamber up to the rear valve-face. The chamber itself is isolated from the influence of the jacket by an annular space, which is filled with a non-conductor. A side-shaft, revolving at one third the rate of the crank-shaft, works the slide-valve at the back of the cylinder by means of a connecting-rod and a rocking-beam. The slide-valve is shown in the horizontal section of the cylinder (Fig. 3), and is formed with ports through which the supply of air and gas is admitted. The gas-valve is raised at the proper instant by a cam, which is shaped to proportion the influx of gas to the speed of the piston. The amount of gas admitted is regulated by the governor, which is driven by the side-shaft. The governor is connected by a rod to the valve, and as it rises it throttles the supply of gas to make it correspond to the work to be done. When the dilution of the charge has been carried as far as is economical, the gas is cut off entirely. A second lever connected with the governor carries a counter-weight, and by altering the position of this weight the speed of the engine can be varied. This lever can be readily put in or out of connection with the governor, its principal object being to enable the engine to be slowed down when not actually doing work. When combustible mixture is to be admitted to the cylinder, the valve-ports coincide with admission, gas, and air inlets, the gas-valve is opened and the charge flows in, following the outward movement of the piston. The first portion of the combustible gases taken in flows down the

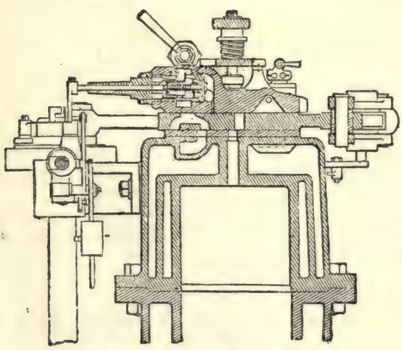


FIG. 3.—Rollason gas-engine.

center of the cylinder until the piston stops, and then it divides and flows back along the walls. This portion, which is diluted with the air in the combustion-chamber, is congregated round the firing-port, while the richer part of the charge is situated next the piston. The

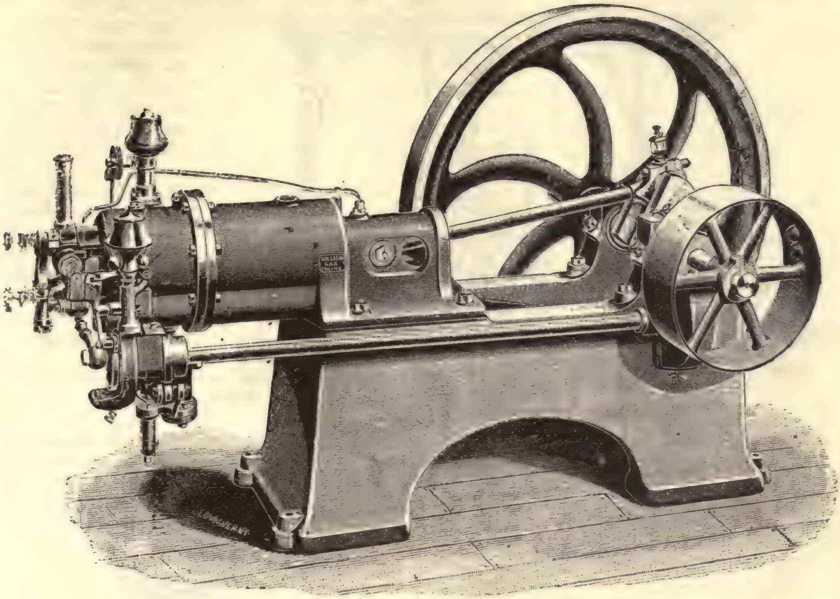


FIG. 4.—Rollason gas engine.

weaker part is ignited first, and the velocity of combustion increases as it approaches the richer part. Prof. A. B. W. Kennedy, of London, made in 1888 a test of this engine under varying conditions, and his report of its performance is published in *Engineering*, May 4th and 11th of that year. The results as to its efficiency are summed up as follows, being the average of four experiments:

Percentage of whole heat of combustion turned into work	19·6
Percentage rejected in jacket water	33
Percentage rejected in exhaust	43·1
Percentage rejected in blank charge and unaccounted for	4·3
	100·0

The mechanical efficiency of the engine on net indicated horse-power during the trials ranged from 86·1 to 90·8; and the consumption of gas per indicated horse-power per hour 20·67 ft. to 21·68 ft.

The Van Duzen Gas-Engine, made by the Van Duzen Gas and Gasoline Engine Co., of Cincinnati, is shown in Fig. 5. The cylinder and water-jacket and pillow-blocks are all of one casting. The base is of one casting, and supports the cylinder at both ends. The governor has direct control over the gas and air valve and the speed of the engine under all conditions. It operates from the crank-shaft to the valve-stems by the use of gear-wheels. Should the main belt break or be thrown off, the supply of gas or gasoline and air would instantly be reduced to such quantity as would be just sufficient to cause the engine to continue to run at the unvarying speed. The govern-

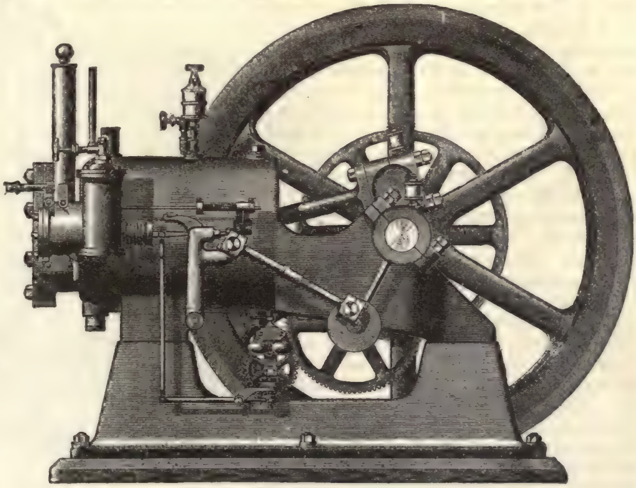


FIG. 5.—Van Duzen gas-engine.

or permits no air to enter the cylinder except when mixed with its proper portion of gas or gasoline. The valves are direct-acting poppet-valves. The gasoline-engine is the same as the gas-engine in every respect, with the addition of a carbureter, which is attached to the air-pipe, and extends from the cylinder off to one side. The tank supplying the gasoline is usually placed outside the building. The carbureter is connected directly to, and is under the complete control of, the governor, and only makes the gas as it is called upon by the governor, and all the gas is consumed as it is made. The engine is built in sizes up to 30 horse-power.

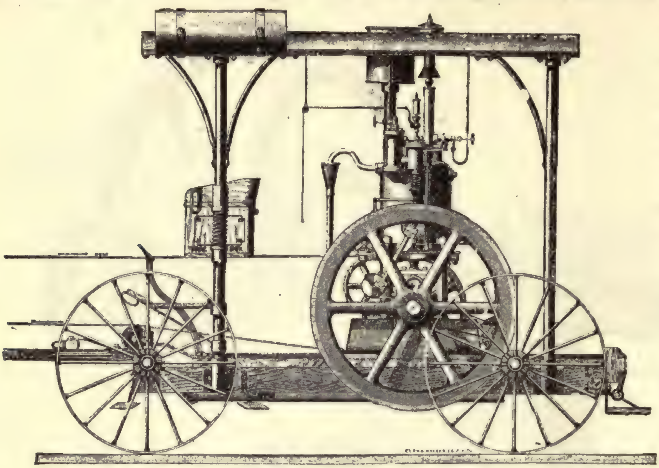


Fig. 6.—Van Duzen portable gas-engine.

The Van Duzen Portable Gasoline-Engine, shown in Fig. 6, is of the upright or vertical type, but is similar in general details to the horizontal engine above described. It is mounted on a light truck, and is housed-in to protect it from the weather. The tank containing the gasoline is braced to the roof. The engine is chiefly used for agricultural purposes.

The Naphtha-Engine.—Naphtha-engines, which utilize naphtha both as the fuel under the boiler and as the fluid to be vaporized in the boiler and used in the engine, have recently come into somewhat extensive employment as motors for light launches. The advantages for this purpose, as compared with a steam boiler and engine, are lightness and compactness, and the shortness of time in which the engine can be started after the fire is lighted. The naphtha launch-engine made by the Gas-Engine and Power Co., of New York, is shown in Figs. 7, 8, 9, and 10. Fig. 7 is a general view of the engine in a launch, Figs. 8 and 9 are respectively longitudinal and cross sections of the engine, and Fig. 10 a sectional view of the boiler or retort. The frame is a box-shaped casting *A*, somewhat in the form of a trough. To the top is bolted the valve-seat A^2, and to this again the cover *B*. The main shaft is coupled to the propeller-shaft. The valve-shaft *D* is arranged above and parallel with the main shaft, longitudinally, of the valve-chest *B*. There are three single-acting cylinders, open at their lower ends, and closed at their upper ends, the only communication from the valve-chest to the cylinders being through the inlet-port *e* (Fig. 8). The cranks are placed at angles of 120°. The valve-shaft *D* has three cranks for regulating the throw of the valves, which are set a little in advance of the lower cranks, so as to give lead to the valves. A free exhaust is thus secured, and the pistons are cushioned on the return strokes. Ball-and-socket joints connect the pistons and rods. The pistons are elongated, having large bearing surfaces.

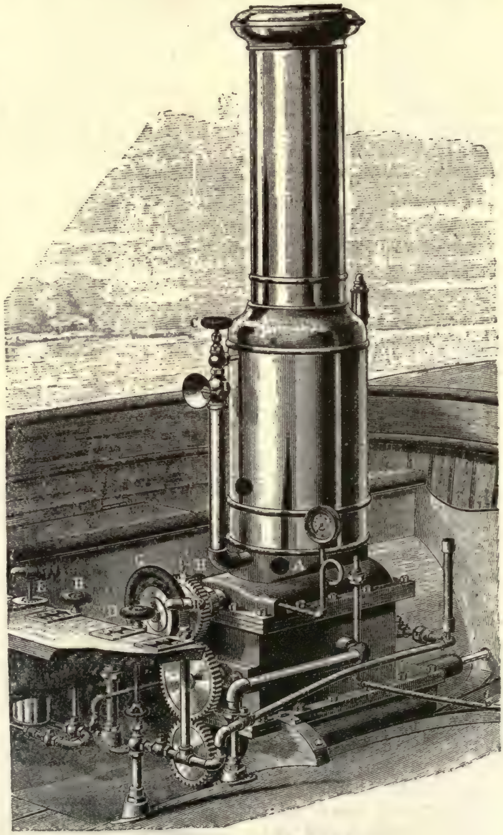


Fig. 7.—Naphtha-engine and boiler.

The slide-valves F (Fig. 8) are each provided with two parallel upright lugs, forming a guide-jaw, in which is fitted a square slide-block bored through horizontally to receive the corresponding crank-pin of the valve shaft D. The induction opening of the valve is marked f, which, when above the port e, admits the live vapor from the valve-chest to the cylinder. Between the lips of the valve is the ordinary arch or channel, which, when in the position shown in Fig. 8, establishes communication between the port e and the exhaust port. An automatic naphtha-pump is arranged at the rear end of the trough A^1 above the main shaft and in line with the row of cylinders. At opposite sides through the valve-chest are horizontal openings, the one for a pressure-gauge, and the other for a safety-valve. A vertical channel connects the safety-valve chamber with the exhaust-chamber and the condensing attachment, so that, when under an excess of pressure the safety-valve opens, the vapor passes direct from the valve-chest to the condenser until safe pressure is restored. Motion is transmitted from the main shaft to the valve-shaft by means of the gears J J^1 and I, the intermediate wheel J^1 turning on a stud secured to the engine-frame.

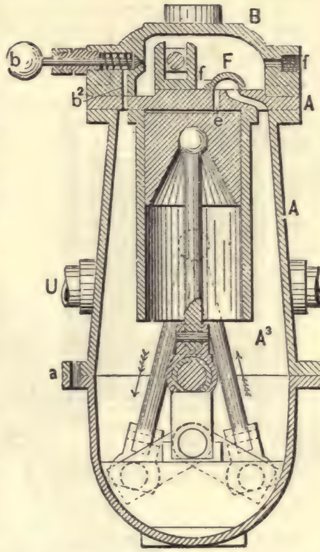


FIG. 8.—Naphtha-engine—section.

The combustion-chamber of the boiler or retort is arranged upon the valve-chest. The feed-pipe from the naphtha-pump and naphtha-tank enter its lower end. It then runs upward coiled, as shown in the figure. The coiled pipe is connected at its upper end by a casting with the pressure-tube O, leading to the valve-chest. Within the tube O is a tube P of smaller diameter. This tube is connected with the injector Q. A valve is provided to regulate the flow of vapor from the pipe P. The pipe Q^2 finally conveys it to the burner immediately over the valve-chest, a suitable supply of air for combustion being drawn in-through the opening Q^1. The burner itself is simply an annular casting held in place by being arranged to surround O and rest upon the nipple. The upper surface of the burner is provided at its circumference with a series of outward holes, through which the flame is thrown against the coils and other parts of the retort for heating the naphtha and converting it into gas.

By this construction it will be seen that the naphtha first passes through the entire coil N upward, thence down into the tube O and through the annular space between this tube and the inner tube P. Thence the greater portion of the gas enters through the pipe O to the steam - chest, and thence through the cylinders. At the same time a portion of the highest grade of the gas, or that which has the least density, passes up, as indicated by the arrow, into the inner tube P, and thence to the injector, in passing through which latter it draws air through the vent Q^1, and thus charged with air passes into the burner. Draft for the burner is provided by side openings at the lower end of the combustion-chamber, and the gas of combustion passes up through the smoke-stack.

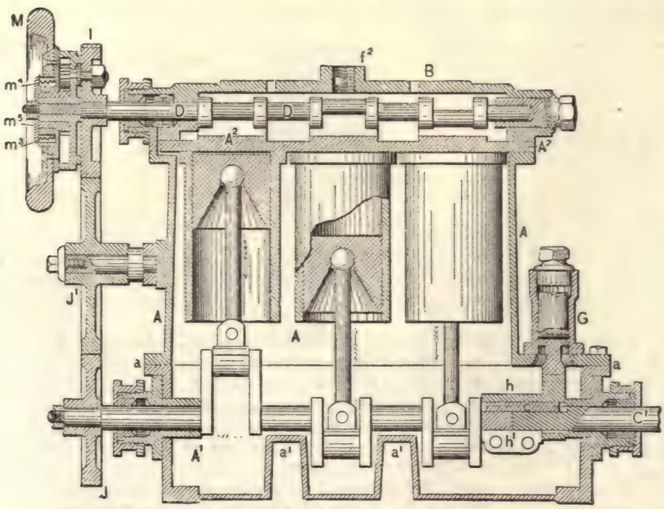


FIG. 9.—Naphtha-engine—section.

In starting the engine the air-valve B is opened, and the air-pump E (Fig. 7) given a sufficient number of strokes to force gas from the tank through the outlet-pipe to the burner, where it is ignited and heats the retort. The naphtha-valve D also is opened, and from five to ten strokes given to the naphtha-pump F. This pumps naphtha from the tank in the bow of the boat into the retort, and, if the latter has been sufficiently heated, pressure will at once be indicated on the gauge. The injector-valve C, as already explained, regulates the flow of gas to

the burner, and hence the speed and pressure. The consumption for a 2-horse-power engine is given at from three quarts to one gallon per hour, and for a 4-horse-power engine at from four to six quarts per hour. The vapor consumed is practically that which goes to the burner, since that which performs work in the engine is exhausted into condensing-pipes running along the bottom of the boat, and is forced by the engine back to the tank, being thus used over and over again. The builders recommend the use of 76° deodorized naphtha. A 2-horse-power engine weighs 200 lbs., a 4-horse-power, 300 lbs., and an 8-horse-power, 600 lbs., or, as the builders claim, less than one fifth the weight of other engines and boilers of the same power. It takes only about two minutes to get under headway.

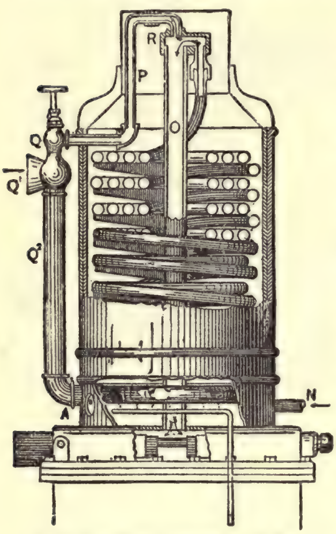


FIG. 10.—Naphtha-engine boiler.

Experiments with the Naphtha-Engine.—Recent experiments have been made by the Gas-Engine and Power Co., the builders of these engines, to test the relative value of hydrocarbon vapor and ordinary steam as an evaporating agent to produce work from heat in small motors, with the following results: A small ordinary steam-engine was used, with a friction-brake on a fly-wheel to measure the useful power, while indicator-diagrams taken from the cylinder showed the power developed by the working agent. A vertical steam-boiler was heated by a large gas-burner, so that the exact quantity of heat could be obtained and regulated by the gas-meter record. In one case steam was taken from the boiler to the working cylinder in the usual way, and the exhaust steam from the cylinder was condensed in a coil of pipe immersed in water, allowed to flow into a hot-well, passed on to the feed-pump of the engine, and forced back into the boiler, thus making a complete circuit. With constant water-level in the boiler, the steam-pressure was 50 lbs. per sq. in. at the start, and it was brought up to this at the end of each trial of three hours' duration. In the case of naphtha, a copper coil was fitted inside the steam-space at the upper part of the same boiler, so that the boiler efficiency should be the same as in the previous experiment. Naphtha of 0·68 specific gravity was pumped into the coil and vaporized by the heat of the steam. The vapor passed to the engine, worked the same piston in the cylinder, was led into a condensing coil, passed to a hot-well, and finally pumped back into the coil inside the boiler.

The tests made alternately with steam and naphtha gave the following results:

	WORKING AGENT.	
	Steam.	Naphtha.
Gas consumption in cubic ft. per hour	82·20	83·48
Mean pressure naphtha in coil (lbs. per sq. in.)	......	55·80
Mean pressure steam in boiler	37·99	30·07
Mean speed in revolutions per min	312·6	552·2
Tension on brake in lbs	1·154	1·222
Work on brake in foot-pounds per min	2,524	4,722

Thus, with nearly the same rate of gas-consumption, the power obtained on the brake was in the ratio of about 5 : 9 for steam and naphtha—that is, the same quantity of heat was turned into nearly twice as much work by the expansion of vapor as by the expansion of steam under the same conditions.

Naphtha, being a complex mixture of various hydrocarbons, evaporates far more rapidly than water. Proper care must be taken in using the naphtha, as the more volatile vapors pass off at the ordinary atmospheric temperature. Other vapors escape as the temperature rises, and there is not uniformity in the rate of evaporation when naphtha is heated. Experiment shows that a given quantity of heat will evaporate nine times as much of this naphtha as of water at atmospheric pressure. On the other hand, this naphtha only expands to $\frac{1}{5}$ the volume of vapor that water yields. Hence, a given quantity of heat can produce $\frac{9}{5}$ times the volume of vapor from naphtha of 0·68 gravity that it would of steam at the ordinary atmospheric pressure. Now we know that the greater the range of temperature through which we can cool a gas by its own expansion, doing work in a perfect heat-engine, the greater the fraction of its sensible heat will be turned into work. To turn all its sensible heat into work would require infinite expansion to the absolute zero of temperature, which is impossible; besides, the gas would be changed into the liquid and solid states long before that extreme degree of cold could be reached. With exhaust at atmospheric pressure, the lower limit of the working range of temperature in every case is the boiling-point of the liquid. In the case of the naphtha used in the above experiments, this lower temperature was 130° F., being cooled through a range of 90° F. Under these conditions, steam could only be cooled to 212° F., through a range of 265° F. to 212° F., or 53° F. Therefore, since the efficiency in

a perfect heat-engine depends only on the working-range of temperature, we see that this efficiency with steam and naphtha would be in the ratio of about 5 : 9.

Again, owing to the small latent heat of evaporation of naphtha, which is only $\frac{1}{5}$ that of water, the loss of heat to the cooling water will be very much less when condensing naphtha than with steam; but then less heat is given to the liquid naphtha to convert it into vapor to begin with; so that in the case of naphtha smaller quantities of heat are being dealt with, and larger portions converted into work by greater pressure during expansion. Hence, for a given power, machinery of much less weight is required with naphtha than with steam. With due precautions to avoid explosions of inflammable vapor, naphtha is found in practice to afford greater convenience of working, owing to the rapidity with which it evaporates, as well as to its oily nature, enabling it to act as lubricant to the engine-cylinder.

The Altmann-Küppermann Petroleum-Motor.—Fig. 11 shows the petroleum-engine of Messrs. Altmann & Küppermann, of Berlin. The cylinder is vertical and single-acting, containing a long piston, packed with five rings, to prevent the leakage of the products of combustion, and surrounded with a water-jacket. At its upper part it has two horns, which carry the bearings of the crank-shaft, at one end of which are a fly-wheel and driving-pulley, and at the other end a bevel-wheel, which drives the governor and the valve-gear. The valves are all of the mushroom type. There is a vapor inlet-valve, an air inlet-valve, and an exhaust-valve, each worked by a separate cam on a small horizontal shaft driven from the lower end of the governor-spindle.

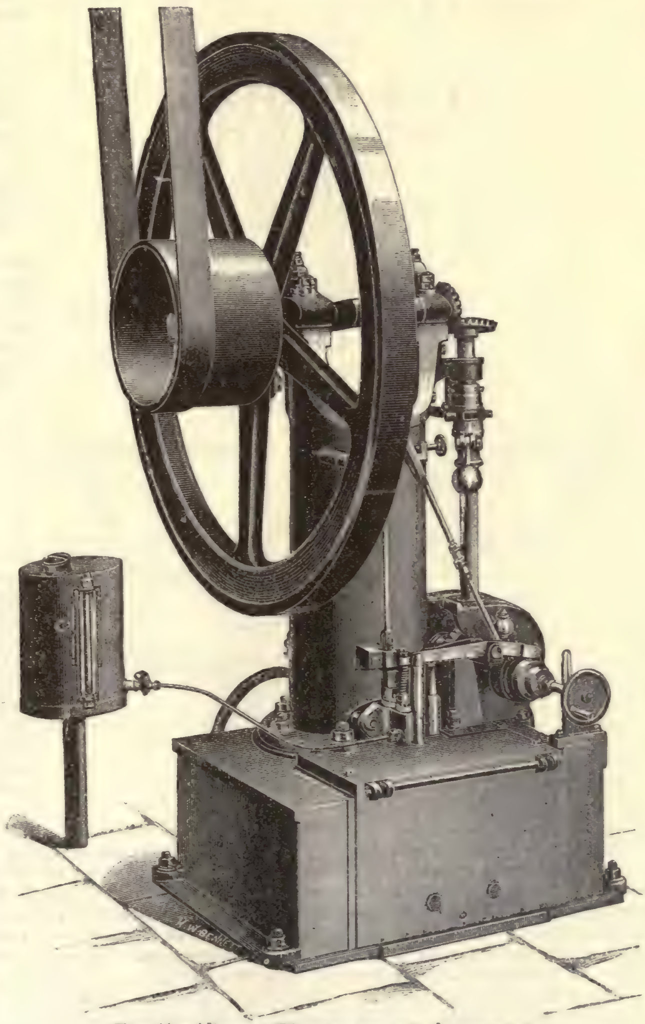


Fig. 11.—Altmann-Küppermann petroleum-motor.

The store of oil for the day's working is kept in the vessel shown on the left. A pipe leads from the vessel to a small pump, which makes one stroke for every two revolutions of the engine. The length of stroke can be varied. The general control of the engine is effected, however, by the governor, which entirely cuts off the supply of oil when the speed is too high. To this end a small valve, placed in front of the pump, and kept down by a strong spring, is lifted by a cam to allow the oil to pass to the pump during normal working. But if the speed is too high, the governor shifts the cam sidewise, so that its raised position no longer comes under the roller at the end of the lever which controls the valve, and consequently the latter can not open. The oil which passes the pump enters a small copper retort, kept red-hot by means of a lamp, and is there converted into vapor, which is drawn into the cylinder when the vapor-valve is lifted by the cam. This is the same cam that operates the oil-control valve. The ignition of the charge is effected in the usual way by means of an incandescent tube, heated in the first instance by the same lamp as the retort. This lamp has no chimney, and burns ordinary paraffin-oil with a blue flame, like a Bunsen gas-jet. The oil is forced through the nozzle by air-pressure created by a small pump, and is vaporized by coming into contact with a hot metal spreader. The ex-

haust-valve is not visible in the engraving, as it is at the back of the cylinder. It is worked by a cam, and can be readily removed for cleaning. The consumption of oil per horse-power per hour is said to be from ·185 to ·238 gallon in the smaller sizes of one or two horse power, and ·132 to ·159 gallon in the larger sizes.

ENGINES, HYDRAULIC. *Pearsall's Hydraulic Engine* is shown in Fig. 1. It is thus described by Mr. H. D. Pearsall, of London, the inventor, in a paper read before the American Institute of Mining Engineers in February, 1889:

"The engine or machine acts on the principle of the hydraulic ram to this extent: that both obtain their pumping power by the arrest of a column of water which has been previously set in motion by gravity. The feature of hydraulic rams which has restricted them to a small size is their violence. In the new machine this is not only reduced but has no existence at all. It works with all the smoothness of a well-constructed reciprocating engine. This is best shown by indicator-diagrams taken from the pressure-chamber. Some of these are given in Fig. 2. These diagrams were taken with ordinary steam-engine indicators.

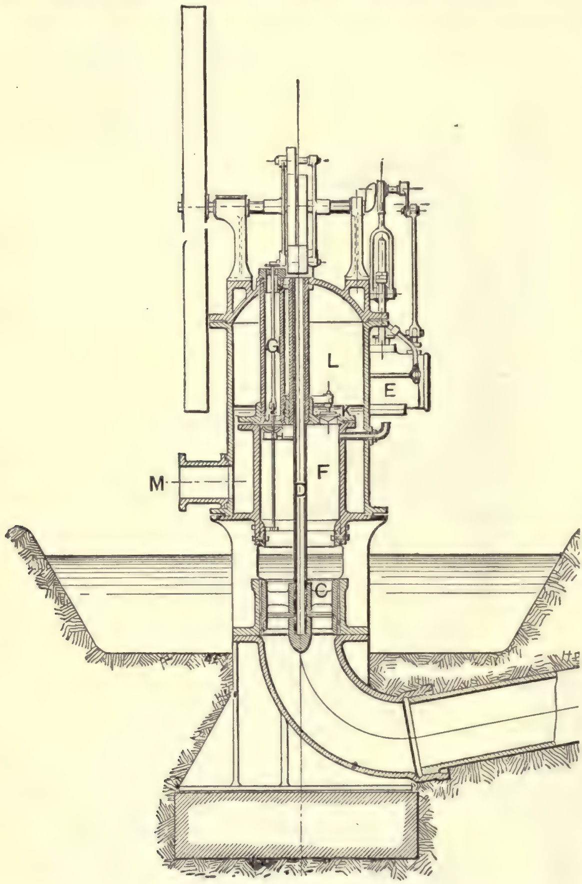


FIG. 1.—Pearsall's hydraulic engine.

"The construction, as shown in Fig. 1, is as follows: *C* is the main valve (here shown open) in the pipe (called a flow-pipe) which conducts water to the engine. *D* is a rod attached to valve *C*, by which it is moved up and down at proper intervals of time by means of the motor *E*. *F* is a chamber immediately above valve *C*. At the period of the stroke of the engine, which is represented in the figure, this chamber contains only air, and communicates freely with the atmosphere by the pipe *G*. At the base of pipe *G* there is a valve, *J*, which carries a float. When the main valve *C* is raised and closed, it of course shuts off the flow of water; but it does not interfere with the flow of the water until it is completely closed, because, until the chamber *F* is filled with water up to the float *H*, the valve *J* remains open, giving free communication between chamber *F* and the atmosphere; consequently, the air freely escapes from the chamber and the water freely rises in the chamber. This action takes place during the closing of the main valve *C*. The consequence is, that no power is wasted in forcing water through the narrowing orifice. A second consequence is, that there is no necessity to close this valve with great rapidity (which is necessary in hydraulic rams). As a matter of fact, it is closed by a gradually retarded motion, and so comes to rest without any concussion. When the water touches the float *H* it closes the valve *J*, shutting off the passage for escape of air, and the pressure in the chamber then rises to the point at which the valves *K* open, and some of the water flows into the air-vessel *L*, from which it of course is constantly flowing out through delivery-pipe *M*. A little air still remains in the chamber. This air is compressed and enters the air-vessel, and is used to drive the motor which actuates the main valve. The column of water flowing in the flow-pipe is thus brought to rest entirely by the elastic resistance of air. When it has ceased to flow, the main valve is again opened, the water with which the chamber *F* is now full escapes, the air-valve *J* falls open, admitting atmospheric air, and the water again begins to flow and to escape through valve *C*. As regards the efficiency with which the engine works, careful experiments have been made, gauging accurately the quantities of water used and delivered, and their respective heads. The head of supply was 17 ft. When head of delivery was 150 ft. the efficiency was 70 per cent, and when the head was 100 ft. the efficiency was 72 per cent."

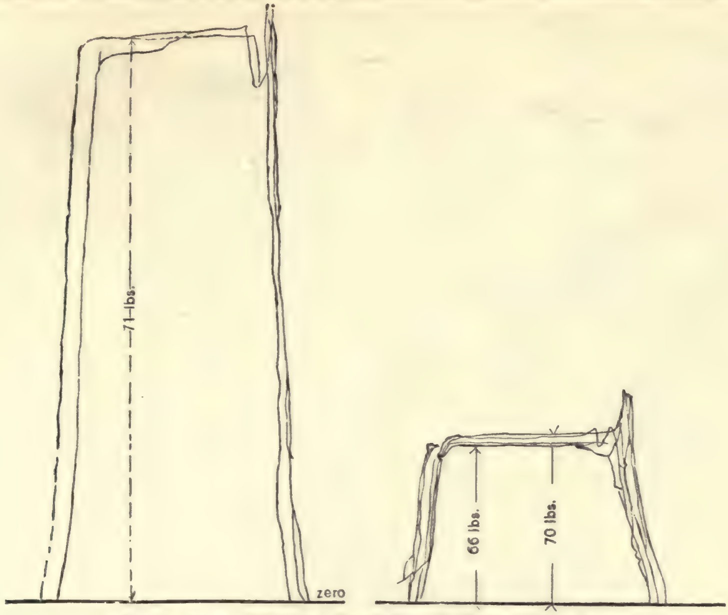


FIG. 2.– Pearsall's hydraulic engine. Indicator—diagrams.

Hydraulic Rams.—The following descriptions of experimental hydraulic rams are taken from a paper by John Richards, of San Francisco (*Proc. Inst. Mech. Engrs.*, Feb., 1888): "Fig. 3 represents a small ram having an inlet-pipe *I* of from 2 to 3 in. diameter. *D* is the discharge-pipe; *C* the check or foot valve; *A* the air-vessel; and *V* and *E* are the escape-valves fixed on the same stem. A plan of the top of the lower valve *E* is shown. The two valves *V* and *E* being nearly balanced, the difference of their areas constitutes the measure of the upward or closing force, which is of course much less than in the case of a single valve. The valves fall by their weight in the usual manner, and are raised partly by the stream rushing out round the upper valve *V*, but mainly by the upward pressure of the issuing current against the curved shield *S* fixed on the valve-stem. In working this form of ram it has been found that accurate adjustment was required to suit the head or fall of the driving-water; and also that the shock was too great for the safety of small rams.

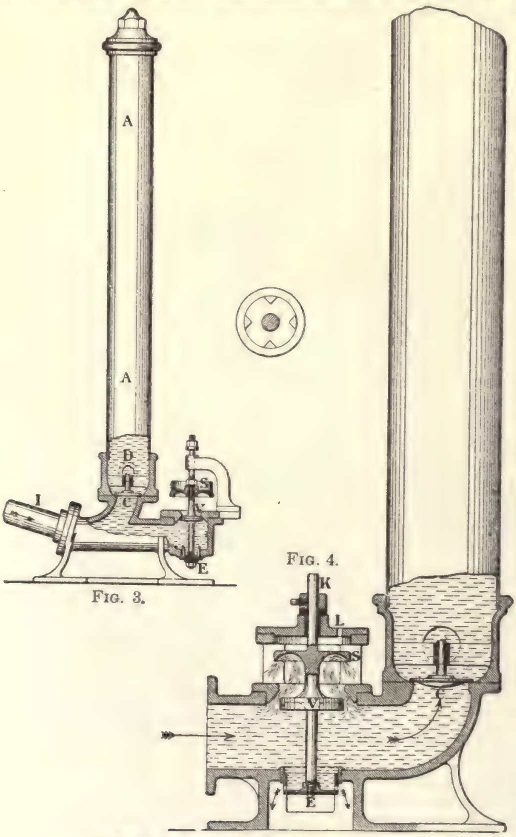


FIG. 3. FIG. 4.

FIGS. 3, 4.—Richards's hydraulic ram.

"In the ram shown in Fig. 4 the two escape-valves *V* and *E* are arranged to pass up freely through their seats, and are stopped by an air-cushion at the top. The waste water nearly all escapes at the upper valve *V*, small outlets only being provided in the lower valve *E* for permitting sand to escape if any should be carried into the machine. The closing is effected mainly by the upward pressure of the issuing stream against the curved shield *S*. When the valves are shot upward in closing, the shield enters the air-chamber above it, in which it fits as a piston, and the momentum is thereby checked without the least

shock. An air-cock is inserted in the top of the air-chamber at *L*, for regulating the amount of resistance offered by the air-cushion. Additional weight, if required for opening the valves, is added on the top of the valve-stem at *K*; it is found, however, that the higher the delivery head the less is the weight required, because of the reflux. Shifting valves were at first applied, but seemed unnecessary. Rams arranged in this manner work without noise or jar, and give a high efficiency for forcing four to five times the height of the propelling head, and are suitable in most cases for irrigating purposes; but when the resistance is increased, the elastic blow or percussive impulse of the current is not enough to raise the check-valve *C* against the increased area caused by its lap.

"In Figs. 5 to 8 is shown another arrangement of hydraulic ram, in which the escape-valve is opened by independent mechanism. The water enters at *I*, and the waste escapes at the

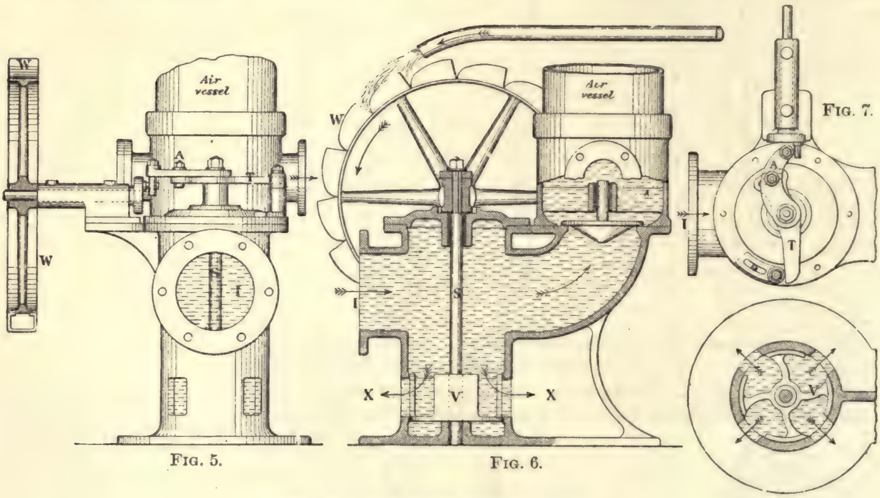


FIG. 5. FIG. 6. FIG. 7. FIG. 8.

FIGS. 5–8.—Richards hydraulic ram.

bottom through four holes shown in the sectional plan, Fig. 8. These holes are alternately covered and uncovered by the four wings of the oscillating valve *V*, which is mounted on a spindle *S*. The valve is opened by means of the water-wheel *W*, and the tappet motion shown in Figs. 5 and 7. The two tappets, coming in contact at each revolution of the water-wheel, open the valve to such an extent as may be determined by the adjusting screw, set in the slot at *A*. As soon as the tappets disengage, the valve is closed by the reaction of the issuing stream against its curved ribs or vanes, as shown in Fig. 8, the motion being arrested by the tail *T* of the tappet-arm, Fig. 7. In this manner the motions of the waste-valve *V* can be controlled at will, and a greater efficiency attained than with the ordinary method of employing the force of the issuing stream for closing the valve by lifting it. Experiments have not yet been made to determine the most effective motion of the valve with respect to the time of closing; but the indications point to variable requirements in this respect, depending on the resistance offered or the height to which the water is being raised."

ENGINES, MARINE. I. TYPES OF ENGINES.—*The Triple-Expansion Engine.*—Fig. 1 represents the latest type of triple-expansion engines used in the high-speed twin-screw British cruisers Thetis, Terpsichore, and Tribune. They were built by James & George Thomson, of Glasgow. In the design the makers have obtained over 13 indicated horse-power per ton weight of machinery in working order, with water in boilers and condenser.

The engines are of the triple-expansion vertical inverted type. Each set of engines is placed in a separate engine-room with a fore-and-aft bulkhead dividing them, and each is in all respects exactly similar. The cylinders are 33½, 49, and 74 in. in diameter, respectively, with a stroke of 3 ft. 3 in. Each cylinder is made of an entirely independent casting, and they are connected by steel stay-rods securely attached to each casting. To still further increase their stability the column-heads have stout cast-steel struts fitted in between them. The receivers consist entirely of copper pipes. The whole of the cylinders are steam-jacketed. The working barrels of the high-pressure and intermediate-pressure cylinders are of forged steel, but those of the low-pressure cylinder are of specially hard, close-grained cast iron. Piston-valves working in separate liners are fitted to the high-pressure and intermediate-pressure cylinders, and the low-pressure cylinder has a flat, double-ported slide-valve with a special type of relief ring at the back. Balance-cylinders are fitted to the valves of all three cylinders, to reduce the strain on the valve-gear as far as possible. The valve-gear is of the double-eccentric, link-motion type, all joints having exceptionally large surfaces. A double-cylinder reversing-engine is provided, and the reversing shaft-levers are fitted with screw-gear to allow of the expansion in each cylinder being altered independently of the others. The back columns are of cast steel, with separate pinned-on faces for the guides, and the front

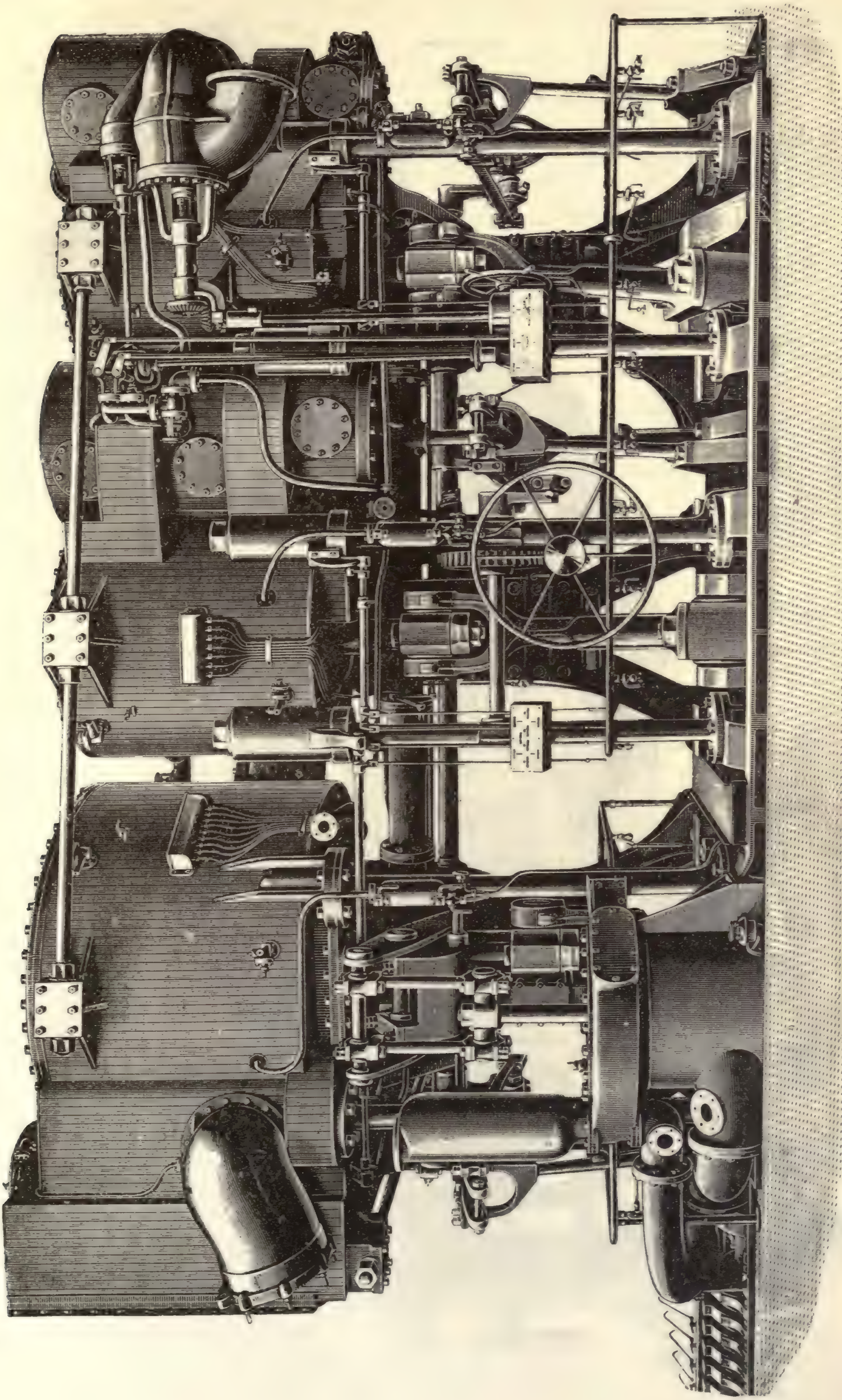


Fig. 1.—Triple-expansion marine engine.

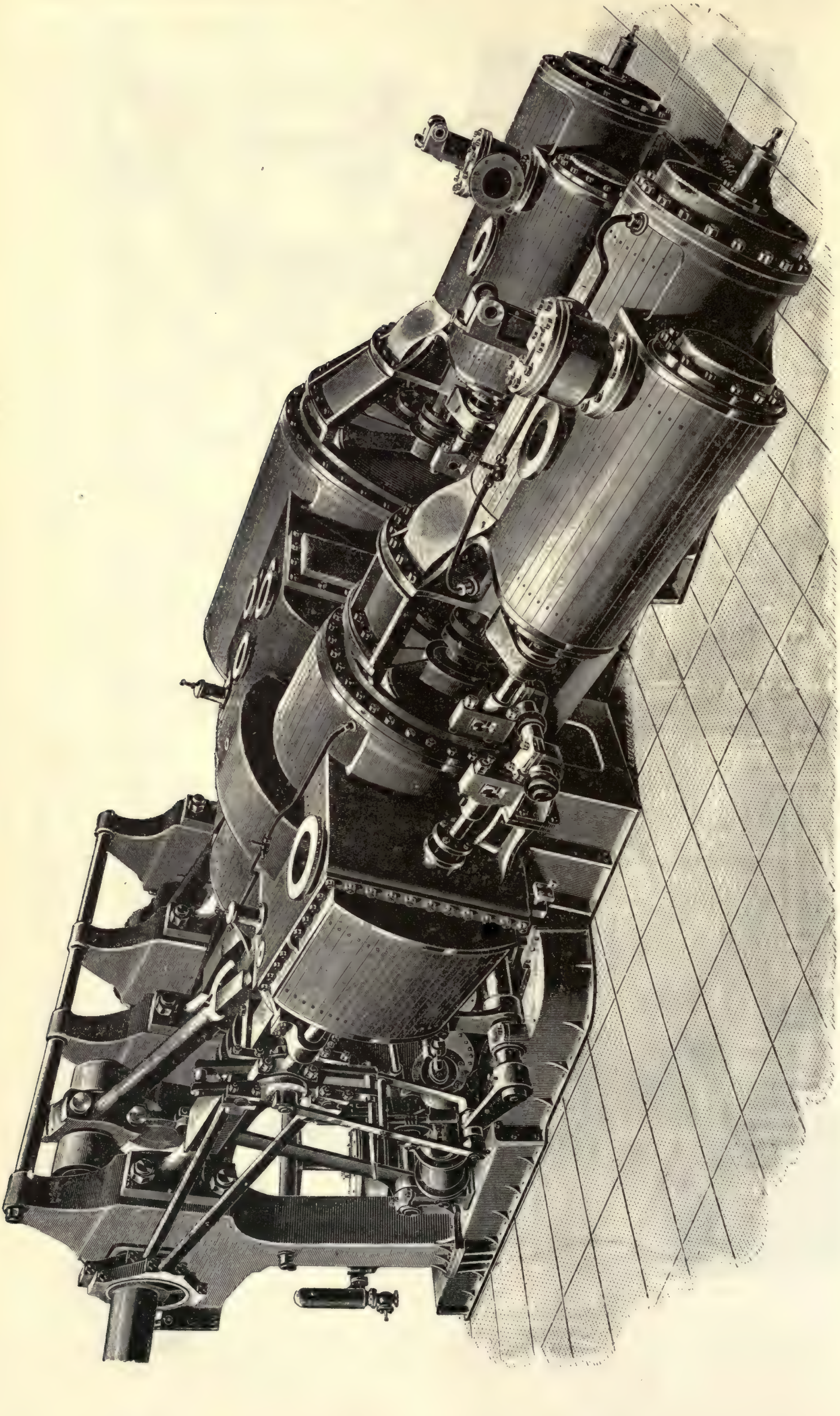


Fig. 2.—Triple-expansion paddle-wheel engine.

columns are of forged steel, thus giving a clear view from the starting platforms which are arranged in the wings of the ship.

To insure the desired lightness, the main condensers, which have a collective cooling surface of 10,000 sq. ft., have casings and ends built up entirely of naval brass plates riveted together. The steam is condensed outside the tubes, and the circulating water passes through them, and is supplied by two large 14-in. Gwynne centrifugal pumps, the discharges from which are connected by an athwart-ship pipe having sluice-valves at each end, and also in the middle, where it passes through the longitudinal bulkhead. The crank and propeller shafts are hollow, of fluid-compressed steel, and the crank-arms are cut away as much as possible for lightness and convenience in fitting the centrifugal lubricators for the crank-pins. The thrust blocks and collars are of cast steel; the latter are lined with white metal and are of the horseshoe type, each separately adjustable. The screw-propellers are three-bladed, and with the bosses and all connections are of gun-metal.

The exhausts from the whole of the auxiliary machinery in the ship are led into an auxiliary exhaust-pipe which is connected with two auxiliary condensers, each of which has its own air and circulating pump entirely independent of those for the main condensers. The combined cooling surface of the two auxiliary condensers is 1,000 sq. ft. In addition to the aforementioned auxiliary machinery there are in each engine-room a set of air-compressing engines and reservoirs, electric-light engines and dynamos, a Weir main-feed pump with patent automatic regulating gear, two bilge and fire pumps, a small pump for the drain-tanks, and two evaporators and distillers, each having independent steam-pumps.

Steam at 155 lbs. pressure is supplied by five steel return tube-boilers, three of which are double-ended, 13 ft. in diameter by 18 ft. 6 in. long, and two single-ended, 13 ft. in diameter by 9 ft. 7 in. long. The total grate-surface is 573 sq. ft., and total heating surface 15,404 sq. ft. In all cases each furnace has a separate combustion-chamber, the draft from which may be controlled independently by dampers fitted in the uptakes. The stoke-holes can be worked both under natural and forced draft; for the latter purpose eight fans 5 ft. in diameter are fitted, capable of maintaining an air-pressure of 3 in. of water if required for testing the tightness of the whole of the space put under pressure, but the maximum allowed on the forced-draft trial is $1\frac{1}{2}$ in. of water.

Triple-Expansion Paddle-Wheel Engine.—Fig. 2 shows the engines of the Hygeia, a paddle-wheel steamer built on the Clyde in 1890. The Hygeia is 300 ft. in length, 32 ft. beam, and 12 ft. in depth. The engines are constructed on Rankin's patent "disconnective" triple-expansion principle, especially designed for high-speed river-steamers. They are of the diagonal direct-acting type, and have two high-pressure cylinders, each 28 in. in diameter, and placed behind an intermediate and a low pressure cylinder 56 and 86 in. in diameter, respectively, with a piston-stroke of 66 in., working tandemwise, in connection with a double-throw shaft. There is only one pair of stuffing-boxes between each pair of cylinders, and ample space has been provided for the easy removal of the intermediate and low pressure cylinder-covers, which, in addition, have been fitted with man-holes and doors for examining the pistons without disturbing the covers. All the pistons have deep cast-iron packing-rings held

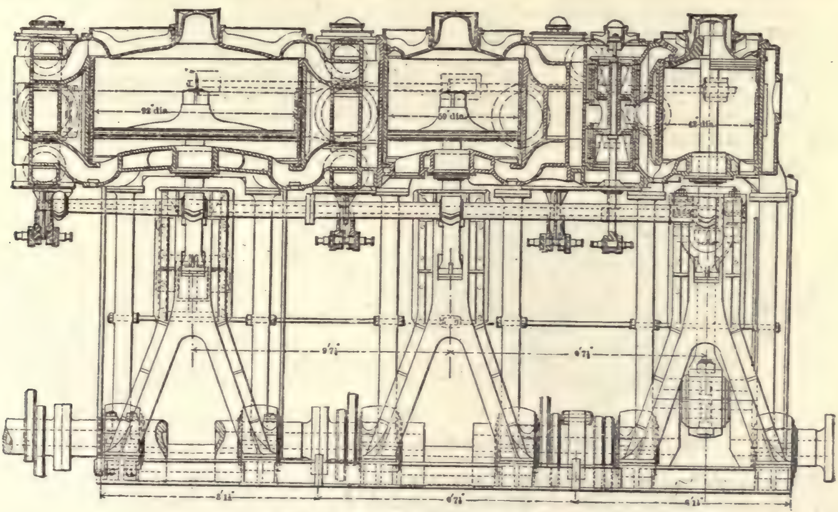


FIG. 3.—Triple-expansion engine.

up to the bore of the cylinders by short spiral steel coils. The two high-pressure cylinder-valves are of the piston type, the intermediate being on the trick principle, and the low-pressure is double-ported. The valve motion consists of the double-barred link type, and is actuated by one of Brown's steam and hydraulic reversing-engines, the starting lever for which, along with the lever for the throttle-valves, is brought to the main-deck platform, and constitutes a

particularly simple arrangement, as, in consequence of there being two high-pressure cylinders, no starting-valves are required, and it is impossible for the engines to stick on the dead-centers, so that prompt handling is always assured.

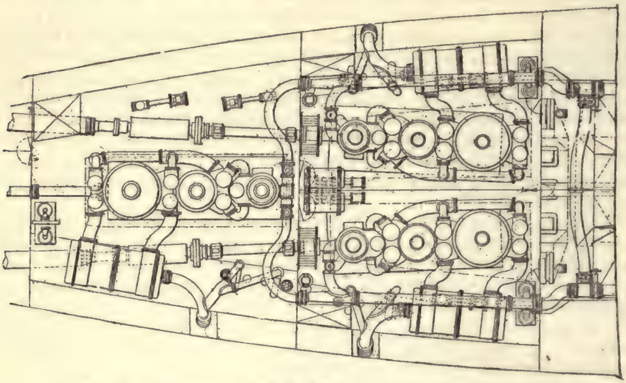


FIG. 4.—Three-screw United States cruiser engines—plan.

The diagonal framings have been made of wrought iron, strongly bolted to heavy brackets cast on the cylinders with round, solid flanges, and they are attached at the other ends by T-heads to the massive main-bearing framings, which are of cast iron and box section. These are firmly bolted to the sole-plates, which bind the whole structure rigidly together. The piston-rods are of forged steel, carefully fitted into the pistons and cross-heads with a good taper and shoulder, and secured by deep malleable iron nuts. The cross-heads and connecting-rods are of forged iron, and the latter are coupled to the cross-heads by double jaws, and to the crank-pins by single jaws, all being fitted with phosphor-bronze bushes of extra large surface, secured by polished wrought-iron covers with strong steel bolts and nuts recessed into guard-rings having set pins. The cranks, shafting, and paddle-arms are of forged iron; the paddle-wheels are of the feathering description with outside rings. The Hygeia on her official trial showed an average speed of 22·8 statute miles, the best run being at the rate of 23½ statute miles. The absence of vibration in both hull and engines, and the exceptionally smooth working of the latter, were noticeable.

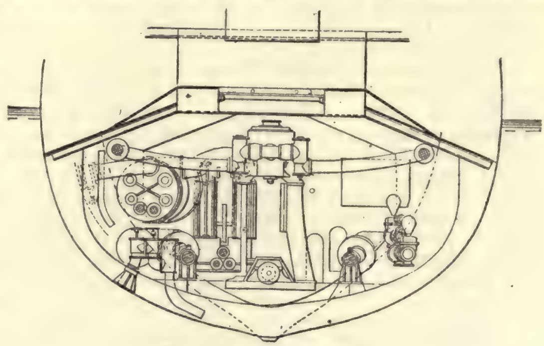


FIG. 5.—Transverse section.

Triple-Screw Engines.—Within the last four or five years twin-screw steamships have come generally into use, especially for transatlantic vessels and for ships-of-war. The United States Government, however, has gone a step further, and is now building a protected cruiser with three screws. The special advantage of three screws in a cruiser, adapted both for high speed when occasion requires and for slow speed for ordinary voyages, is that by stopping either one or two engines fuel can be

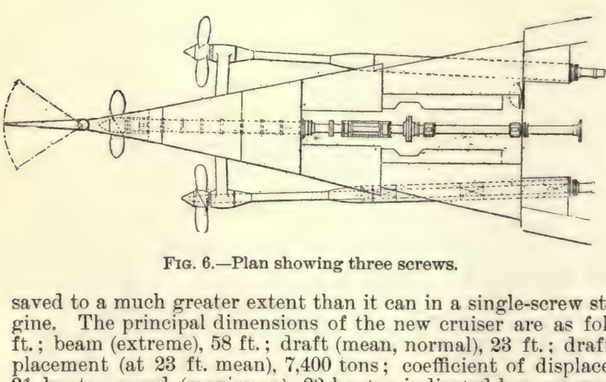


FIG. 6.—Plan showing three screws.

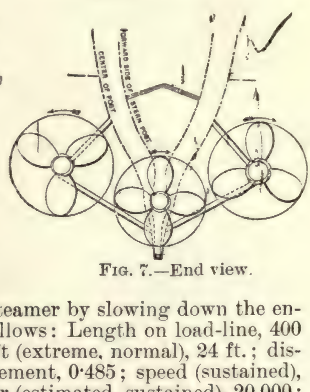


FIG. 7.—End view.

saved to a much greater extent than it can in a single-screw steamer by slowing down the engine. The principal dimensions of the new cruiser are as follows: Length on load-line, 400 ft.; beam (extreme), 58 ft.; draft (mean, normal), 23 ft.; draft (extreme, normal), 24 ft.; displacement (at 23 ft. mean), 7,400 tons; coefficient of displacement, 0·485; speed (sustained), 21 knots; speed (maximum), 22 knots; indicated horse-power (estimated, sustained), 20,000; indicated horse-power (estimated, maximum), 23,000; coal-supply, 2,000 tons; number of screws, 3; outboard screws in diameter, 13 ft. 9 in.; center screw in diameter, 12 ft. There will be three sets of propelling-engines, each set being complete in all respects and placed in separate water-tight compartments. The amidship engine will be placed abaft the port

and starboard engines. The amidship and starboard engines will turn right and the port one left handed when the vessel is going ahead. These engines will be of the vertical inverted cylinder, direct-acting, triple-expansion type, each with a high-pressure cylinder 42 in., an intermediate-pressure cylinder 59 in., and a low-pressure cylinder 92 in. in diameter—the

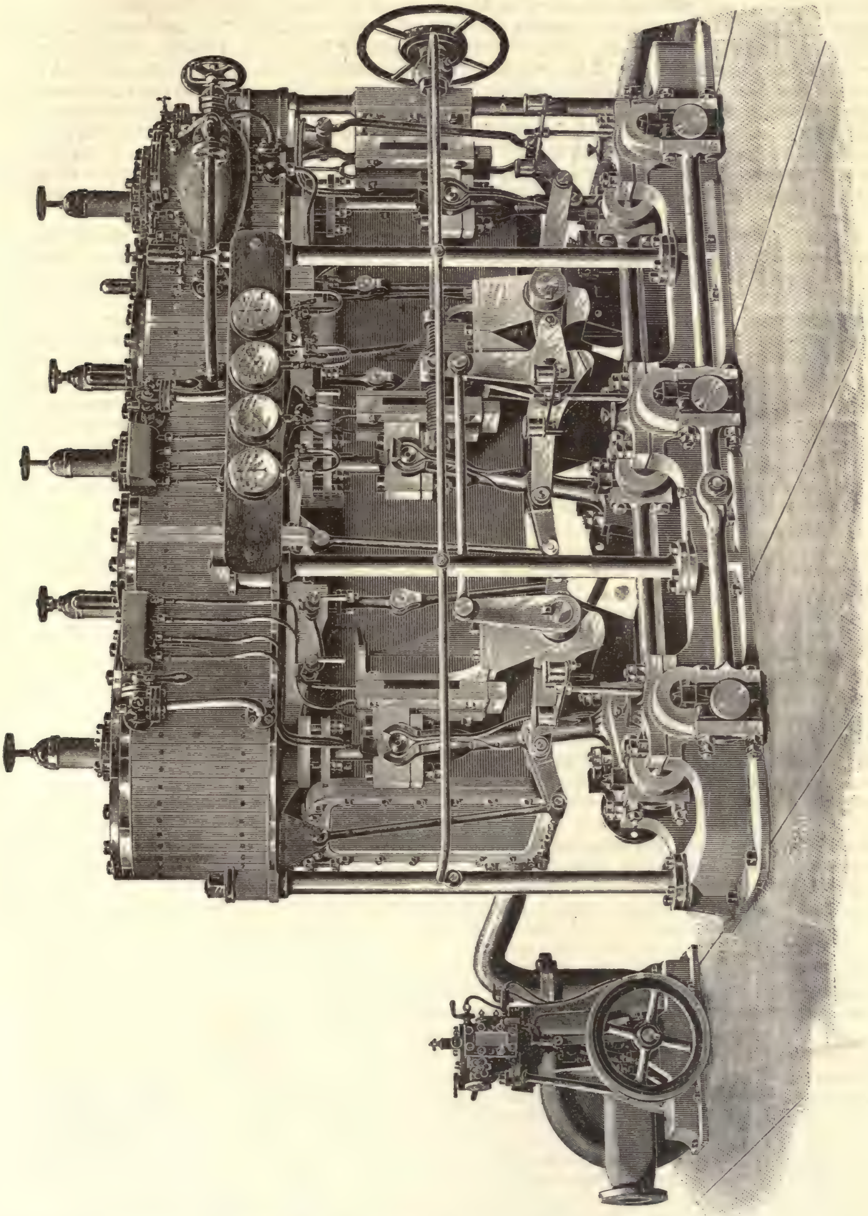


FIG. 8.—Vertical triple-expansion engine.

stroke of all pistons being 42 in. It is estimated that the collective indicated horse-power of propelling, air-pump, and circulating-pump engines should be about 21,000 when the main engines are making about 129 revolutions per min. The high-pressure cylinder of the after engine will be forward and the low-pressure cylinder aft, and the high-pressure cylinder of each forward engine will be aft and the low-pressure cylinder forward. The main valves will be of the piston type, worked by Stephenson link-motions with double-bar links. There will be one piston-valve for each high-pressure cylinder, two for each intermediate-pressure cylinder, and four for each low-pressure cylinder. The framing of the engines will consist of cast-steel inverted Y-frames at the back of each cylinder and cylindrical forged-steel columns

at the front, as shown in figure. The main condenser for each engine will have a cooling surface of about 9,474 sq. ft., measured on the outside of the tubes, the water passing through the tubes. Two of the propellers will be right and one left, to be made of manganese bronze or approved equivalent metal. There will be six double-ended boilers, about 15 ft. 6 in. diameter and 21 ft. 3 in. long, and two about 11 ft. 8 in. diameter and 18 ft. 8½ in. long for the main boilers, and two single-ended auxiliary boilers about 10 ft. diameter and 8 ft. 6 in. long. The boilers will be of the horizontal return fire-tube type, all constructed of steel for a working pressure of 160 lbs. per sq. in. Each of the larger-sized double-ended boilers will have eight corrugated furnace-flues, 3 ft. 3 in. internal diameter; each of the smaller double-ended boilers will have four corrugated furnace-flues, 3 ft. 6 in. internal diameter, and each single-ended boiler will have two furnaces 2 ft. 9 in. internal diameter. The total heating surface for the main and auxiliary boilers will be about 43,272 sq. ft., measured on the outer surface of the tubes, and the grate surface 1,285 sq. ft. The forced-draft system will consist of one blower for each fire-room, discharging into an air-tight fire-room. The full coal-supply of 2,000 tons will give the vessel a radius of action of 26,240 knots, or 109 days steaming at 10 knots per hour.

Fig. 3 is a sectional view of one of the engines of the new cruiser. Fig. 4 shows the arrangement of the three engines in a plan view: Fig. 5 is a transverse section aft of the two forward engines; Fig. 6 is a plan view; and Fig. 7 an end view showing the position of the three screws.

The steamer Wai, constructed by Dunsmuir & Jackson, Glasgow, for passenger service on one of the rivers on the Bombay coast, India, is 90 ft. long by 20 ft. broad, and 3 ft. 3 in. draft when fully loaded. The propelling engine (Fig. 8) is a vertical, three-cylinder, triple-expansion, surface-condensing engine, placed athwart the vessel, each cylinder forming a separate engine, and driving its own crank-shaft and propeller, the three engines being connected together by two side-rods. The cylinders are 9, 14½ and 25 in. diameter and 10 in. stroke. They are designed for a pressure of 200 lbs. per sq. in., and to run 300 revolutions per min. The propellers are of gun-metal, each 2 ft. 6 in. diameter, with three blades. The center screw is placed in the usual aperture in the stern, and the two outside screws a few feet farther forward. (*Engineering*, Aug. 21, 1891, p. 211.)

Quadruple-Expansion Engines for Torpedo-Boats.—Messrs. Yarrow & Co. recently built six first-class torpedo-boats for the Argentine navy, 130 ft. long and 13 ft. 6 in. wide on the water-line. The first five were fitted with triple-compound engines, and on their official trials of two hours' continuous run, and fully equipped for service, attained speeds of somewhat over 23 knots per hour, the mean of all the trials being 23·312 knots. The sixth boat, called the Bathurst, was fitted with a quadruple-compound engine. The cylinders are 14 in., 20 in., 27 in., and 36 in. diameter, and have a stroke of 16 in. The order of position is high, second intermediate, first intermediate, and low. The valves are all of the piston type. The chief object in view in placing quadruple-expansion engines in this boat was to do away with, or perhaps rather to materially reduce, the vibration that is so unpleasant a feature in modern high-speed craft with quick-running engines. A very fair measure of success has been attained in this direction, sufficient to warrant the extra room and expense due to the introduction of the additional cylinder. Under the same conditions of consumption the average horse-power of five first-class boats with triple-compound engines was 1,120, indicated; while on the Bathurst 1,230 indicated horse-power has been registered; so that there was a gain of 110 indicated horse-power. On the trial the mean speed was 24·453 knots, while on the two hours' run the speed was but a trifle less—24·426 knots. There is therefore a gain of over a knot, presumably due to the additional cylinder. The load carried was 12 tons, and the displacement 75·5 tons. The steam-pressure was 200 lbs.; first receiver, 75 lbs.; second receiver, 35 lbs.; third receiver, 4 lbs. Forced draft was used, the air-pressure in the stokehold averaging 3·2 ins. The engines made about 435 revolutions per min. (See *Engineering*, Nov. 21, 1890.)

II. Marine-Engineering, Progress in.—Mr. Alfred Blechynden, of Barrow-in-Furness, England, contributed a highly interesting illustrated paper on Marine-Engineering to the Liverpool meeting of the Institution of Mechanical Engineers, 1891 (see *Engineering*, Aug. 21 and Sept. 18, 1891), giving a review of progress during the last decade. We shall abstract liberally from his paper in what follows:

Since 1881 the three-stage expansion-engine has become the rule, and the boiler-pressure has been increased to 160 lbs. and even as high as 200 lbs. per sq. in. Four-stage expansion-engines of various forms have also been adopted. The increase of working pressure and other improvements have brought with them their equivalent in economy of coal, which is about 20 per cent. Marked progress has been made in the direction of dimension, more than twice the power having been put into individual vessels.

Forced Draft.—There are several methods by which the principle known as forced draft may be practically applied. In its earlier English use stoke-holds were adopted, the air being delivered into them by fans at a pressure varying from about 1 in. to 3 in. of water. This arrangement has the merit of keeping the stoke-holds cool, and its details are simple; but it is dirty, and where bunker-doors are not well fitted great discomfort may be caused on deck. Possibly, also, it is not quite so economical as the closed ash-pit system; but such exact data as exist of its working indicate that with moderate air-pressure it is at least no less economical than natural draft. The American practice is to close the ash-pits, and take the delivery-tubes from the fans into them. This, though involving more ash-pit fittings, is certainly advantageous so far as cleanliness is concerned; the furnaces are also not subjected to the severe strains caused by the inrush of cold air which occurs during firing with closed stoke-holds.

As often fitted, it has the disadvantage of making rather a hot stoke-hold, though with sufficient precautions there is no reason why the ventilation should not be made perfect by taking the air through the stoke-holds. In the earlier American experiments (see Isherwood's *Experimental Researches*, vol. ii, Trials of Gunboats of Chippewa Class and Fulton) the air was introduced into the ash-pits by pipes at the back ends.

Forced draft has also been produced by placing a fan in the uptake, and exhausting through the furnaces. This plan has the great advantage of dispensing with the elaborate furnace-fittings common to the undergrate systems; but it has the disadvantage of the difficulty of keeping the fan in working order, owing to the high temperature in the chimney, and has not as yet come into common use; and, according to the researches of Dr. Tyndall on combustion in condensed and attenuated atmospheres, it should result in a more perfect combustion, but how far this is realized in practice is not determined.

In regard to the economy of forced draft, an examination of Table III will show that while the mean consumption of coal in those steamers working under natural draft is 1·573 lb. per indicated horse-power per hour, it is only 1·336 lb. in those fitted with forced draft. This is equivalent to an economy of 15 per cent. Part of this economy, however, may be due to the other heat-saving appliances with which the latter steamers are fitted. Such evidence as exists shows that not only is forced draft more economical as regards quantity of coal, but by its means such classes of coal may be used as would not without it be worth putting on board. It is in this direction perhaps that the greatest saving has followed its employment.

Thus far the following would appear to be a fair summary of the advantageous points attending the use of forced draft: First, it seems fairly well established that, if the boilers are well constructed and are provided with ample room to insure circulation, their steaming-power may without injury be increased to about 30 or 40 per cent over that obtained on natural draft for continuous working, and may be about doubled for short runs; secondly, such augmentation is accompanied in normal cases by an increased consumption per indicated horse-power; but, thirdly, the same or even greater power being indicated, it may with moderate assistance of forced draft be developed with a smaller expenditure of fuel, the grates, etc., being properly proportioned; fourthly, forced draft enables an inferior fuel to be used; and, fifthly, under certain conditions of weather, when with normal proportions of boiler it would be impossible to maintain steam for the ordinary speed with natural draft, the normal power may with forced draft be insured. In particular cases any or all these advantages may be a source of economy; and the first of them may render possible that which would otherwise be impracticable.

Marine Boilers.—No particular change can be recorded in the general design of the marine boiler, but the change of material used and the great advance which has taken place in the application of tools to boiler-making can not pass without notice. As a material for the plates of boilers, iron is giving place to steel, though it seems probable that it will continue yet awhile to be the material for tubes. Furnaces are made with corrugated, ribbed, and spiral flues, with the object of giving increased strength against collapse without abnormally increasing the thickness of the plate. The increased pressures adopted in marine boilers have tended to cause a reduction in size, and as the high pressures have caused thicker scantlings, the larger boilers have become very heavy. The boilers of the R. M. S. Empress of India, which were 16 ft. 3 in. in diameter by 19 ft. 6 in. long, weighed 85 tons each, without furnace-fittings or mountings of any description. (See BOILERS.)

Engine.—The change from the principle of two-stage expansion to that of three and of four stages has been attended with corresponding modifications in the engine. The desire to economize in length of engine has given rise to more varieties of arrangement than any other single cause. For this purpose, combined with the aim of making them more accessible, the valves have been removed from the fore and aft center line and placed behind or in front, and worked either by one of the numerous forms of radial valve-gear, or by the link-motion and levers. It is true that by such an arrangement the length over the cylinders can be diminished; but as the extent to which the distances between the centers can be reduced is limited by the lengths of the shaft-bearings and the thicknesses of the cranks and couplings, little can be gained below the cylinders by this means.

The most common types of triple-engines have the cylinders arranged in the sequence—high, intermediate, low; the condenser forms part of the engine-framing, and the pumps are placed at the back of the condenser and worked by levers. In the smaller engines the cylinders are rigidly bolted together; but in the larger they are free, and connected only by a pair of bar-stays fixed to their centers. This is customary, in order to prevent the extension of the distance between the centers when the engines are heated; but it is a point which appears more important in theory than in practice, and it is doubtful whether the greater rigidity of the bolted cylinders in the smaller engines is not a much more important feature in ordinary work. In naval vessels vertical engines are now almost uniformly adopted, and the necessary protection for the cylinders is obtained by an armored hatch. In the later designs the larger engines are made open-fronted, with standards of cast steel at the back and wrought-steel pillars in front. Feed, bilge, and circulating pumps are worked by separate engines. For the air-pumps also separate engines have sometimes been adopted, and they possess great merits for manœuvring purposes, as the vacuum can be maintained and the condenser kept clear of water while the main engines are standing, and the latter are thus ready to answer more instantly any order which may be given. With the three-crank engine, however, this is of less importance than with the two-crank type. In modern cruisers, which are designed with the view of steaming upon emergency at a very high speed, and ordinarily at about half that rate,

the engines become much too large for the power developed at slow speeds, and in consequence are not economical under the ordinary condition of working. In larger vessels this difficulty is met by separating each set of propelling engines into two sets of half the capacity, the one forward of the other, and so arranged that the forward set may be disconnected, with the after set left to do the work. The propelling engines of the Italian cruisers Lepanto, Italia, Re Umberto, and Sardegna, and of the British cruisers Blake and Blenheim, have been arranged on this plan. The general details of the engine have not undergone many modifications, but still they have not remained without change.

Piston-Valves.—Since high steam pressures have become common, piston-valves have become the rule for the high-pressure cylinder, and are not unusual for the intermediate. When well designed they have the great advantage of being almost free from friction, so far as the valve itself is concerned. It is usual to fit springless adjustable sleeves, which have all the advantages of the old solid ring so far as their freedom from friction is concerned, and in case of leakage they can with ease be adjusted by lining up at their joints. In smaller engines the same springless ring has been used for the pistons of the high-pressure and intermediate cylinders. It may not give such absolute steam tightness as the spring ring, but any little leakage can be picked up in the low-pressure cylinder, and such very slight loss of efficiency as may be due to this cause should be fairly well compensated by the diminished friction of the valves. For low-pressure cylinders piston-valves are not in favor; if fitted with spring rings their friction is about as great as, and occasionally greater than, that of a well-balanced slide-valve; while if fitted with springless rings there is always some leakage, which is irrecoverable. But the large port clearances inseparable from the use of piston-valves are most objectionable; and with triple-engines this is especially so, because with the customary late cut-off it becomes difficult to compress sufficiently for insuring economy and smoothness, and working when in "full gear," without some special device.

Feed-Water Heating.—Weir's system is founded on the fact that, if the feed-water as it is drawn from the hot-well be raised in temperature by the heat of a portion of steam introduced into it from one of the steam-receivers, the decrease of the coal necessary to generate steam from the water of the higher temperature bears a greater ratio to the coal required without feed-heating than the power which would be developed in the cylinder by that portion of steam would bear to the whole power developed when passing all the steam through all the cylinders. The temperature of the feed is of course limited by the temperature of the steam in the receiver from which the supply for heating is drawn. Supposing, for example, a triple-expansion engine were working under the following conditions without feed-heating: Boiler pressure, 150 lbs.; indicated horse-power in high-pressure cylinder, 398; in intermediate and low-pressure cylinders, together, 790; total, 1,118; and temperature of hot-well, 100° F. Then with feed-heating the same engine might work as follows: The feed might be heated to 220° F., and the percentage of steam from the first receiver required to heat it would be 10·88 per cent, the indicated horse-power in the high-pressure cylinder would be as before, 398, and in the intermediate and low-pressure cylinders it would be 10·88 per cent less than before, or 705, and the total would be 1,103, or 93 per cent of the power developed without feed-heating. Meanwhile the heat to be added to each pound of the feed-water at 220° F. for converting it into steam would be 1,005 units, against 1,125 units with feed at 100° F., equivalent to an expenditure of only 89·4 per cent of the heat required without feed-heating. Hence, the expenditure of heat in relation to power would be $89{\cdot}4 \div 93 = 96{\cdot}4$ per cent, equivalent to a heat economy of 3·6 per cent. If the steam for heating can be taken from the low-pressure receiver, the economy is about doubled.

Feed-Water Evaporators.—In order to make up the losses of water due to leakage of steam from safety-valves, joints, etc., in engines supplied with surface-condensers, it was formerly customary to pump water from the sea into the boilers. This involved deposit on the internal surfaces, and consequent loss of efficiency and danger of accident through overheating the plates. With the higher pressures now adopted the danger arising from overheating is much more serious, and the necessity is absolute of maintaining the heating surfaces free from deposit. This can be done only by filling the boilers with fresh water in the first instance, and maintaining it in that condition. To do this two methods are adopted, either separately or in conjunction; either a reserve supply of fresh water is carried in tanks, or the supplementary feed is distilled from sea-water by special apparatus provided for the purpose.

In the construction of the distilling or evaporating apparatus advantage has been taken of two important physical facts, namely, that if water be heated to a temperature higher than that corresponding with the pressure on its surface, evaporation will take place; and that the passage of heat from steam at one side of a plate to water at the other is very rapid. In practice the distillation is effected by passing steam, say from the first receiver, through a nest of tubes inside a still or evaporator, of which the steam space is connected either with the second receiver or with the condenser. The temperature of the steam inside the tubes being higher than that of the steam either in the second receiver or in the condenser, the result is that the water inside the still is evaporated, and passes with the rest of the steam into the condenser, where it is condensed and serves to make up the loss. This plan localizes the trouble of deposit and frees it from its dangerous character because an evaporator can not become overheated like a boiler, even though it be neglected until it salts up solid. When the tubes do become incrusted with deposit, they can be either withdrawn or exposed, as the apparatus is generally so arranged, and they can then be cleaned.

Screw-Propellers.—An extensive series of experiments on screw-propellers was made, under the direction of Mr. Blechynden in 1881, with a large number of models, the primary object

being to determine what value there was in a few of the various twists which inventive ingenuity can give to a screw-blade. The results led the experimenters to the conclusion that in free water such twists and curves are valueless as serving to augment efficiency. The experiments were then carried further, with a view to determine quantitative *moduli* for the resistance of screws with different ratios of pitch to diameter, or "pitch ratios," and afterward with different ratios of surface to the area of the circles described by the tips of the blades, or "surface ratios."

One of the most important results deduced from experiments on model screws is that they appear to have practically equal efficiencies throughout a wide range both in pitch ratios and in surface ratio, so that great latitude is left to the designer in regard to the form of the propeller.

Another important feature is that, although these experiments are not a direct guide to the selection of the most efficient propeller for a particular ship, they supply the means of analyzing the performances of screws fitted to vessels, and of thus indirectly determining what are likely to be the best dimensions of screw for a vessel of a class whose results are known. Thus a great advance has been made on the old method of trial upon the ship itself, which was the origin of almost every conceivable erroneous view respecting the screw-propeller. The fact was lost sight of that any modifications in form, dimensions, or proportions referred only to that particular combination of ship and propeller, or to one similar thereto, and so something like chaos was the result. This, however, need not be the case much longer.

In regard to the material used for propellers, steel has been largely adopted for both solid and loose bladed screws, but unless protected in some way the tips of the blades are apt to corrode rapidly and become unserviceable. One of the stronger kinds of bronze is often judiciously employed for the blades in conjunction with a steel boss. Where the first extra expense can be afforded bronze seems the preferable material; the castings are of a reliable character, and the metal does not rapidly corrode; the bronze blades can therefore with safety be made lighter than steel blades, which favors their springing and accommodating themselves more readily to the various speeds of the different parts of the wake. (References: *Trans. Inst. Naval Architects*, 1886–'87; *Proc. Inst. Civ. Engrs.*, 1890; *Northeast Coast Inst. of Engrs. and Ship-builders*, vol. vii, 1890–'91.)

Twin Screws.—The great question of twin-screw propulsion has been put to the test upon a large scale in the mercantile marine. While engineers, however, are prepared to admit its advantages so far as greater security from total breakdown is concerned, there is by no means thorough agreement as to whether single or twin screws have the greater propulsive efficiency. What is required to form a sound judgment upon the whole question is a series of examples of twin and single screw vessels, each of which is known to be fitted with the most suitable propeller for the type of vessel and speed; and until this information is available little can be said upon the subject with any certainty.

The following table shows some recent examples of twin-screw steamers:

TABLE I.—*Passenger-Steamers fitted with Twin Screws.*

VESSELS.	Length between perpendiculars.	Beam.	CYLINDERS, TWO SETS IN ALL CASES.		Steam pressure.	Indicated horse-power.
			Diameters.	Stroke.		
	Ft.	Ft.	In.	In.	Lbs.	
City of Paris / City of New York	525	63¼	45, 71, 113	60	150	20,000
Teutonic / Majestic	565	58	43, 68, 110	60	180	18,000
Normannia	500	57½	40, 67, 106	66	160	11,500
Columbia	463½	55½	41, 66, 101	66	160	12,500
Empress of India / Empress of Japan / Empress of China	440	51	32, 51, 82	54	160	10,125
Oriel	415	48	34, 54, 85	51	160	10,000
Scott	460	54½	34½, 57½, 92	60	170	11,656

Twin screws offer an opportunity for reducing the weight of all that part of the machinery of which the weight relatively to power is inversely proportional to the revolutions for a given power. This can be reduced in the proportion of 1 to 52—that is, to 71 per cent of its weight in the single-screw engine; for, since approximately the same total disk is required in both cases with similarly proportioned propellers, the twins will work at a greater speed of revolution than the single screw.

Weight of Machinery.—It is interesting to compare the weight of machinery relatively to the power developed; for this comparison has sometimes been adopted as the standard of excellence in design in respect of economy in the use of material. The principle, however, on which this has generally been done is open to some objections. It has been used to compare the weight directly with the indicated horse-power, and to express the comparison in pounds per horse-power. So long as the machinery thus compared is for vessels of the same class and working at about the same speed of revolution, no great fault can be found; but as speed of revolution is a great factor in the development of power, and as it is often dependent on circumstances altogether external to the engine and concerning rather the speed of the ship, the engines fitted to high-speed ships will thus generally appear to greater advantage than is their due. Leaving the condenser out of the question, the weight of an engine would be much better referred to cylinder capacity and working-pressures, where these are materially

TABLE II.—*Dimensions, Indicated Horse-Power, and Cylinder Capacity of Three-Stage Expansion Engines in Nine Steamers, and Weight in Relation thereto.*

Number of steamer.	Single or twin screws.	CYLINDERS. Diameters.			CYLINDERS. Stroke.	Revolutions per min.	Boiler pressure per sq. in.	Indicated horse-power.	Cylinder capacity.	HEATING SURFACE. Total.	HEATING SURFACE. Per indicated horse-power.	WEIGHT OF MACHINERY. Engine-room.	WEIGHT OF MACHINERY. Boiler room.	WEIGHT OF MACHINERY. Total.	RELATIVE WEIGHT OF MACHINERY. Per indicated horse-power. Engine-room.	RELATIVE WEIGHT OF MACHINERY. Per indicated horse-power. Boiler-room.	RELATIVE WEIGHT OF MACHINERY. Per indicated horse-power. Total.	RELATIVE WEIGHT OF MACHINERY. Engine-room, per cub. ft. of cylinder capacity.	RELATIVE WEIGHT OF MACHINERY. Boiler-room, per 100 sq. ft. of heating surface.	Type of machinery.
			In.		In.		Lbs.		Cub. ft.	Sq. ft.	Sq. ft.	Tons.	Tons.	Tons.	Lbs.	Lbs.	Lbs.	Tons.	Tons.	
1	Single.	40	66	100	72	64·5	160	6,751	522	17,640	2·62	681	662	1,343	226	220	446	1·30	3·75	Mercantile.
2	"	39	61	97	66	67·8	160	5,525	436	15,107	2·73	638	619	1,257	259	251	510	1·46	4·10	"
3	"	23	38	61	42	83	160	1,450	109	3,973	2·73	134	128	262	207	198	405	1·23	3·23	"
4	"	17	26½	42	24	90	150	510	30	1,403	2·75	38·8	46·2	85	170	203	373	1·29	3·30	"
5	Twin.	32	54	82	54	88	160	9,625	508	20,193	2·10	719	695	1,414	167	162	329	1·41	3·44	"
6	"	15	24	38	27	113	150	1,194	55	3,200	2·68	75·2	107·8	183	141	202	343	1·37	3·37	"
7	Single.	20	30	45	24	191	145	1,265	36·3	2,227	1·76	44	61	105	77	108	185	1·21	2·72	Naval horizontal.
8	Twin.	18½	29	43	24	182·5	140	2,105	66·2	3,928	1·87	73·5	109	182·5	78	116	194	1·11	2·78	"
9	"	33½	49	74	39	145	150	9,400	319	15,882	1·62	262	429	691	62·5	102	165	0·82	2·70	Naval vertical.

different, than directly to the indicated power. In Table II are given the relative weights of nine triple-expansion engines, according to both modes of comparison. Nos. 1 to 6 are mercantile engines, and Nos. 7 to 9 are naval examples. It will be noticed that, though the twin-screw engines Nos. 5 and 6 are the same type of engine as the single-screw engines Nos. 1 to 4, as evidenced by their weights per cubic foot of cylinder capacity, yet their engine-weights per indicated horse-power are considerably lower by virtue of their higher speed of revolution. Comparing its predecessors with No. 9, which is a fair type of a naval engine, it will be seen that the engines usually fitted in the merchant service are about 44 per cent heavier per unit of cylinder capacity than this engine. The low weight per unit of heating-surface in Nos. 7, 8, and 9, which is about 22 per cent less than in the mercantile examples, Nos. 1 to 6, is due to careful use of material, as well as to the lighter scantlings adopted for boilers by the Admiralty.

Economy of Fuel.—Table III gives the performances of 28 three-stage expansion engines in ordinary work at sea. The average consumption of coal per indicated horse-power is 1·522 lb. per hour. The average working-pressure is 158·5 lbs. per sq. in. Comparing this working-pressure with 77·4 lbs. in 1881, a superior economy of 19 per cent might be expected now on account of the higher temperature; or, taking the 1·828 lb. of coal per hour per indicated horse-power in 1881, the present performance under similar conditions should be 1·48 lb. per hour per indicated horse-power. In Table IV the principal factors in the present performance of marine engines are compared with those of 1881, and also with those of 1872, as indicated in the table accompanying Sir Frederick Bramwell's paper (*Proc. Inst. M. E.*, 1872). Compared on the same basis, then, it appears that the working-pressures have been increased twice in the last ten years, and nearly three times in the last nineteen.

The coal consumptions have been reduced 16·7 per cent in the last ten years, and 27·9 per cent in the last nineteen. The revolutions per minute have increased in the ratios of 100, 105, 114, and the piston speeds as 100, 124, 140. Although it is quite possible that further investigations may show that the present actual consumption of coal per indicated horse-power is understated in Table IV, yet it is hardly probable that the relative results will be affected thereby. The returns of the coal consumption have in all cases been taken in the same way and on the same basis as for Mr. Marshall's paper in 1881 (*Proc. Inst. M. E.*, 1881), so that whatever errors may affect the returns for the one year are likely to have affected those for the other. The probability of error lies in the statement of the horse-power indicated, which, when taken directly from the ship's log, is usually in excess of that actually indicated continuously; so that the comparison of coal consumption with power is open to objection.

Valve-Motion.—The old-fashioned link-motion, though it seemed for a time likely to disappear, still holds its own, and in all probability will continue to do so. In the distribution of steam it may not be so mathematically accurate on paper, but practically the effect is or can be made as good as with the best radial valve-gear. It does not give constant lead when linking up, but constant lead is not the ideal of perfect valve-setting. A constant lead angle of the crank is more nearly what is required, for which a diminishing lead in the valve with linking up is the necessary condition. The old link-motion lends itself readily and gracefully to any modifications which may be suggested by changes in the condition of working; the radial forms do not. Besides this, the link-motion admits of simple geometrical treatment, which is generally understood even in the engine-room, and is consequently a safer arrangement in the hands of the man found there.

TABLE III.—*Particulars of Three-Stage Expansion Engines, Boilers, and Results of Trials in Twenty-eight Steamers.*

Number of steamer.	CYLINDERS.		Con-denser, cooling surface.	PROPELLER.		BOILERS.						ENGINES.			HEATING SURFACE.		Indicated horse-power per sq. ft. of grate.	Coal burned per sq. ft. of grate per hour.	Coal burned per indicated horse-power per hour.	REMARKS.
	Diameters.	Stroke.		Diameter.	Pitch.	Number.	Diameter.	Length.	Heating surface, total.	Fire-grate area.	Steam pressure, lbs. per sq. in.	Revolutions per min.	Piston speed, ft. per min.	Indicated horse-power.	Per indicated horse-power.	Per lb. of coal per hour.				
	In.	In.	Sq. ft.	Ft. In.	Ft. In.		Ft. In.	Ft. In.	Sq. ft.	Sq. ft.	Lbs.				Sq. ft.	Sq. ft.		Lbs.	Lbs.	
1......	40 66 100	72	11,586	22 0	28 6	Six.	13 6	18 0	17,640	626	155	52·2	627	4,295	4·11	2·46	6·86	11·45	1·67	H
2......	40 66 100	72	11,586	22 0	28 6	"	13 6	18 0	17,640	626	155	51·3	616	4,402	4·04	2·55	7·03	11·14	1·584	H
3......	39 61 97	66	11,000	20 10	26 0	Five.	13 6	18 0	15,107	540	155	57·3	630	3,587	4·21	2·22	6·65	12·60	1·896	H
4......	39 61 97	66	11,000	20 10	26 0	"	13 6	18 0	15,107	540	155	57·4	631	3,822	3·95	2·14	7·08	13·02	1·841	H
5......	23 38 61	42	2,008	16 0	17 6	Two.	14 6	10 4½	3,972	133	160	61	427	1,120	3·54	2·02	8·43	14·75	1·75	
6......	25½ 42 70	51	3,209	16 6	20 0	"	13 0	17 6	6,162	193	180	61·3	521	1,700	3·62	2·40	8·82	13·25	1·505	
7......	21 34 55½	36	1,447	14 0	17 6	"	13 6	10 0	3,350	99	160	64	384	900	3·72	2·31	9·09	14·67	1·612	H
8......	22 35 59	39	1,430	15 6	15 6	"	13 4	9 9	3,324	102	160	70	455	1,065	3·12	2·38	10·42	13·70	1·312	
9......	29 45 74	54	3,900	19 6	20 0	Three.	12 5	16 9	6,875	240	160	56	504	2,250	3·055	2·04	9·38	14	1·494	H
10......	31 48 82	54	4,150	19 0	19 0	"	12 6	18 6	8,000	260	160	61·5	553	2,600	3·075	2·04	10	15·10	1·505	H
11......	25 41 67	48	2,800	.....	....	Two.	12 6	16 4	4,645	142	160	58	464	1,300	3·57	2·26	9·16	14·46	1·580	
12......	21½ 36 59	42	2,000	15 0	16 6	Three.	12 0	10 3	3,852	122	160	67	469	1,100	3·50	2·29	9·02	13·79	1·529	
13......	32 51 82	54	12,562	16 6	23 0	Four.	16 0	19 0	20,192	710	160	58·5	526	3,670	5·50	3·64	5·17	7·80	1·510	H
14......	27 44 71	48	2,800	17 9	17 6	Two.	13 6	16 6	6,164	220	150	63	504	1,680	3·67	2·12	7·65	13·18	1·723	H
15......	29 45 74	60	4,020	19 0	24 0	"	14 8	16 8	6,950	196	150	53·8	538	2,360	2·94	1·78	12·03	19·85	1·650	
16......	29 45 74	54	3,850	18 0	21 0	"	14 3	17 0	6,960	216	160	64	576	2,550	2·73	1·82	11·80	17·70	1·500	
17......	23 37 64	48	2,400	16 6	18 0	"	11 9	17 0	4,715	144	180	62	496	1,500	3·14	2	10·40	16·31	1·568	
18......	28 44 74	51	3,700	17 9	22 9	"	14 3	18 0	8,000	264	150	62	527	1,727	4·63	2·85	10·53	17·06	1·620	
19......	23 36½ 58	36	2,218	15 0	15 6	One.	14 10	15 5	3,271	126	160	76	456	1,269	2·58	1·84	10·07	14·10	1·400	P
20......	17, 17 38 60	42	2,900	15 6	15 6	Two.	12 0	15 2	4,400	168	150	75	525	1,530	2·875	1·96	9·11	13·32	1·464	P
21......	25 39 62	36	2,700	14 0	16 3	"	12 2	14 0	4,000	150	160	73	438	1,250	3·20	2·40	8·35	11·13	1·330	P
22......	31 46 72	51	3,713	16 3	22 6	Three.	13 0	11 4	5,076	110	150	72	612	2,513	2·02	1·34	22·85	33·95	1·488	D H
23......	22½ 35½ 58½	39	1,750	14 7	16 6	One.	15 0	11 9	2,338	50	160	76	494	1,350	1·73	1·28	27	36·42	1·350	D H P
24......	25 42 68½	48	2,763	16 10	17 9	Two.	14 3	11 6	4,346	84	160	65	520	1,800	2·41	1·94	21·42	26·62	1·242	D H P
25......	22¼ 35¾ 58½	48	3,530	15 6	18 0	"	13 0	11 4	3,486	63	160	69·5	552	1,360	2·56	1·91	21·59	28·90	1·338	D H P
26......	31 50 83	60	6,860	19 0	23 0	"	16 3½	12 0	6,438	154	150	59	590	2,600	2·435	1·78	16·88	23·05	1·365	D H P
27......	32 53 87½	60	7,500	19 0	23 9	Four.	14 6	11 6	8,571	210	160	66	660	3,400	2·52	2·04	16·18	19·97	1·234	D H P
28......	28½ 46 75	42	3,450	16 0	21 0	Three.	14 3½	9 11	6,618	188	160	73	511	2,058	3·215	2·05	17·10	10·92	1·565	
												Average of all twenty-eight...			3·274	2·14	11·22	17·08	1·522	
												" natural draft......			3·560	2·25	8·91	13·92	1·573	
												" forced draft.......			2·412	1·72	20·98	28·15	1·336	

D = Forced draft. H = Feed-heater. P = Pass-over slide-valve.

TABLE IV.—*Actual and Comparative Results of Working of Marine Engines in Three Years, 1872, 1881, 1891.*

BOILERS, ENGINES, AND COAL.	ACTUAL RESULTS.			COMPARED WITH 1872.			COMPARED WITH 1881.		
	1872.	1881.	1891.	1872.	1881.	1891.	1872.	1881.	1891.
Boiler pressure..............lbs. per sq. in.	52·4	77·4	158·5	1·000	1·479	3·020	0·677	1·000	2·048
Heating surface per horse-power....sq. ft.	4·410	3·919	3·274	1·000	0·889	0·743	1·125	1·000	0·837
Revolutions per min..........................	55·67	58·66	63·75	1·000	1·050	1·143	0·949	1·000	1·084
Piston speed....................ft. per min.	376	467	529	1·000	1·241	1·405	0·805	1·000	1·133
Coal per horse-power per hour ....lbs.	2·110	1·828	1·522	1·000	0·866	0·721	1·153	1·000	0·833

Dimensions.—In the matter of the power put into individual vessels considerable strides have been made. In 1881 probably the greatest power which had been put into one vessel was in the case of the Arizona, whose machinery indicated about 6,360 horse-power. The following table gives an idea of the dimensions and power of the larger machinery in the later passenger-vessels:

TABLE V.—*Dimensions and Power of Machinery in later Passenger-Vessels.*

Year.	Name of vessel.	Diameters of cylinders.	Length of stroke.	Indicated horse-power.
		In.	In.	
1881........	Alaska..........................	68, 100, 100	72	10,686
1881........	City of Rome	46, 86 ; 46, 86 ; 46, 86	72	11,800
1881........	Servia...........................	72, 100, 100	78	10,300
1881........	Livadia, yacht..................	60, 78, 78 ; 60, 78, 78 ; 60, 78, 78	39	12,500
1883........	Oregon..........................	70, 104, 104	72	13,300
1884........ 1884........	Umbria....................... Etruria.......................	71, 105, 105	72	14,320
1888....... 1889........	City of New York............. City of Paris..................	45, 71, 113 ; 45, 71, 113	60	20,000, about.
1889........ 1889........	Majestic....................... Teutonic.......................	43, 68, 110 ; 43, 68, 110	60	18,000

In war-vessels the increase has been equally marked. In 1881 the maximum power seems to have been in the Inflexible, namely, 8,485 indicated horse-power. The following will give an idea of the recent advance made.

	Indicated horse-power.
Howe (Admiral class)..	11,600
Italia and Lepanto..	19,000
Re Umberto..	19,000
Blake and Blenheim (building)..	20,000
Sardegna (building)..	22,800

It is thus evident that there are vessels at work to-day having about three times the maximum power of any before 1881.

III. MARINE-ENGINE TRIALS AND PERFORMANCES.—One of the most thorough tests of marine engines that have been published is that of the steamship Iona, made in 1890 by the Research Committee of the Institution of Mechanical Engineers, and reported by Prof. A. B. W. Kennedy.

The Iona has triple-expansion engines on three cranks working a single screw. She is a vessel of 275·1 ft. length, 37·3 ft. breadth, and 19 ft. depth. Her depth, molded, is 21 ft. 10 in., and her coefficient of fineness is 0·765. She has a double bottom of cellular construction 230 ft. long, and can carry 443 tons of water ballast. The mean draft during the trial was 20 ft. 7½ in., corresponding to a displacement of 4,430 tons. The trial was made during a voyage, and was begun when fires were in normal condition and everything warmed up. It lasted 16 hours. A condensed abstract of the trial is given below.

The following are the results of measurements made upon the indicator-diagrams taken, to ascertain the proportion of steam accounted for by them. The actual weight of feed-water used per revolution was 2·35 lbs.:

PROPORTION OF STEAM ACCOUNTED FOR BY INDICATOR-DIAGRAMS.	Lbs. per revolution	Percentage of total feed.	Percentage in jacket or present in cylinder as water.
Steam present in high-pressure cylinder after cut-off, when the pressure was 125·4 lbs. per sq. in. above the atmosphere........	1·49	63·4	33·6
Steam-pressure in intermediate cylinder, when the pressure was 19·4 lbs. per sq. in. above the atmosphere........................	1·76	74·9	25·1
Steam present in low-pressure cylinder near end of expansion, when the pressure was 8·6 lbs. per sq. in. below the atmosphere.	1·39	59·1	40·9

Table VI gives for comparison with the results of the trial of the steamship Iona the results of the trials of four other steamers tested by the Research Committee of the Society of Mechanical Engineers in 1888 and 1889. The figures placed in brackets are considered doubtful.

TABLE VI.—*Comparative Results of the Trials of Five Steamers, Meteor, Fusi Yama, Colchester, Tartar, and Iona.*

1	NAME OF VESSEL	Meteor.	Fusi Yama.	Colchester.	Tartar.	Iona.
2	Date of trial	June 24, 1888.	Nov. 14, 15, 1888.	Nov. 9, 1889.	Nov. 27, 1889.	July 13, 14, 1890.
3	Duration of trial ... hours	17·15	13·95	10·88	10·08	16
4	Type of engines	triple	compound	twin compound	triple	triple
5	Cylinder diameter, high-pressure ... in.	29·37	27·35	(two) 30	26·03	21·88
6	" " intermediate ... "	44·03	.....	......	42·03	34·02
7	" " low-pressure ... "	70·12	50·3	(two) 57	68·95	56·95
8	Stroke, length ... "	47·94	33	36	42	39
9	Boilers, number of main boilers	2	1	2	2	2
10	" single-ended or double-ended	double	single	double	double	single
11	Furnaces, total number	12	3	12	8	4
12	Heating surface, total ... sq. ft.	6,648	2,257	5,820	5,226	3,160
13	" " tubes ... "	5,760	1,689	4,770	4,366	2,590
14	Grate area ... "	208	52	220	161	42
15	Total heating surface to grate area ... ratio	32	43·4	86·5	32·5	75·2
16	Tube surface to grate area ... "	27·7	32·5	21·7	27·1	61·7
17	Grate area to flue area through tubes ... "	.....	4·05	5·51	4·50	2·3
18	" " area through funnel ... "	5·04	3·21	4·77	4·19	1·4
19	Mean boiler-pressure above atmosphere ... lbs. per sq. in.	145·2	56·84	80·5	143·6	165
20	Mean admission pressure, high-pressure cylinder above atmosphere ... lbs. per sq. in.	134·4	50·3	64·3 59·4	121·4	142·5
21	Mean effective pressure high-pressure cyl... " "	58·46	30·74	45·65 42·07	36·89	46·65
22	" " " intermediate cyl.... " "	19·50	.....	......	20·07	20·44
23	" " " low-pressure cyl.... " "	12·38	10·87	13·42 12·42	7·18	7·16
24	Mean effective pressure total reduced to low-pressure cylinder ... lbs. per sq. in.	29·9	19·9	24·8	19·8	21·13
25	Mean exhaust pressure low-pressure cylinder below atmosphere ... lbs. per sq. in.	11·6	10·9	10·6 10·5	10·5	12·74
26	Mean vacuum in condenser below atmosphere " "	12·17	12·48	12·49	12·9	13·88
27	Revolutions per min., mean ... revs.	71·78	55·59	86 87·1	70	61·1
28	Indicated horse-power, mean total ... i. h.-p.	1,994	371·3	1,022·5 957·2	1,087·4	645·4
29	Coal burned per min ... lbs.	66·75	16·45	95·7	32	15·7
30	" per hour ... "	4,005	987	5.742	1,920	942
31	" per sq. ft. of grate per hour ... "	19·25	18·98	26·1	11·93	22·4
32	" per sq. ft. of total heating surface per hour "	0·602	0·437	0·987	0·367	0·298
33	" per indicated horse-power per hour ... "	2·01	2·66	2·90	1·77	1·46
34	Carbon-value of 1 lb. of coal as used ... "	0·878	0·878	0·913	1·031	1·02
35	" equivalent per i. h.-p. per hour ... "	1·76	2·33	2·65	1·82	1·49
36	Feed-water per min ... lbs.	497·7	131	717	359·4	143·4
37	" per hour ... "	29,860	7.860	43,020	21,564	8,616
38	" per sq. ft. of total heating surface per hour "	4·49	3·48	7·39	4·13	2·73
39	" per lb. of coal ... "	7·46	7·96	7·49	[11·23]	9
40	" per lb. of coal from and at 212° F. ... "	8·21	8·87	8·53	[13·06]	10·63
41	" per lb. of carbon-value from and at 212° F. "	9·62	10·10	9·34	[12·67]	10·42
42	" per indicated horse-power per hour ... "	14·98	21·17	21·73	[19·83]	13·35
43	Calorific value of 1 lb. of coal as used ... Th. U.	12,770	12,760	13,280	14,995	14,830
44	Percentage of line 43 taken up by feed-water	62	67·2	62	.....	69·2
45	" " carried away by furnace gases	21·9	23·5	28	22·1	16·2
46	" " lost by imperfect combustion	3·6	0·0	1·3	0·0	0·0
47	" " expended in evaporating moisture in coal	1·2	0·9	0·4	0·0	0·0
48	" " unaccounted for	11·3	8·4	8·3	.....	14·6
49	Heat taken up by feed-water per min ... Th. U.	528,600	141,100	788,700	[403,600]	161,100
50	" turned into work per min ... "	85,240	15,870	84,630	46,490	27,500
51	" taken up by feed-water per i. h.-p. per min... "	265·6	380	398·4	[371·2]	249·6
52	Efficiency of boiler (line 44) ... per cent	62	67·2	62	.....	69·2
53	" of engine (line 50 ÷ line 49) ... "	16·1	11·2	10·7	[11·5]	17·1
54	" of engine and boiler combined (l. 52 × l. 53) "	10	7·6	6·6	9·7	11·8
55	Mean velocity of steam through water-surface in boilers per min ... ft.	.....	6·28	8·6	3·43	1·61
56	Space occupied by boilers per i. h.-p ... cub. ft.	2·72	4·53	2·52	4·33	4·15
57	Weight of engines, boilers, etc., with water, per i. h.-p., tons	0·20	0·27	0·20	0·27	0·31

Performance of Engines of the Steamship City of Paris.—The indicator diagrams shown in Fig. 9 are reduced from cards published in the *American Machinist* of February 12, 1891. The following particulars are given in connection with the cards. The scale of the original cards was $\frac{1}{64}$ for the high-pressure, $\frac{1}{32}$ for the intermediate, and $\frac{1}{16}$ for the low-pressure. The engraved cards here shown are four ninths of the size of the original.

(For details of the quickest passages made by the City of Paris, see section *Performances of Atlantic Steamers*, p. 294.)

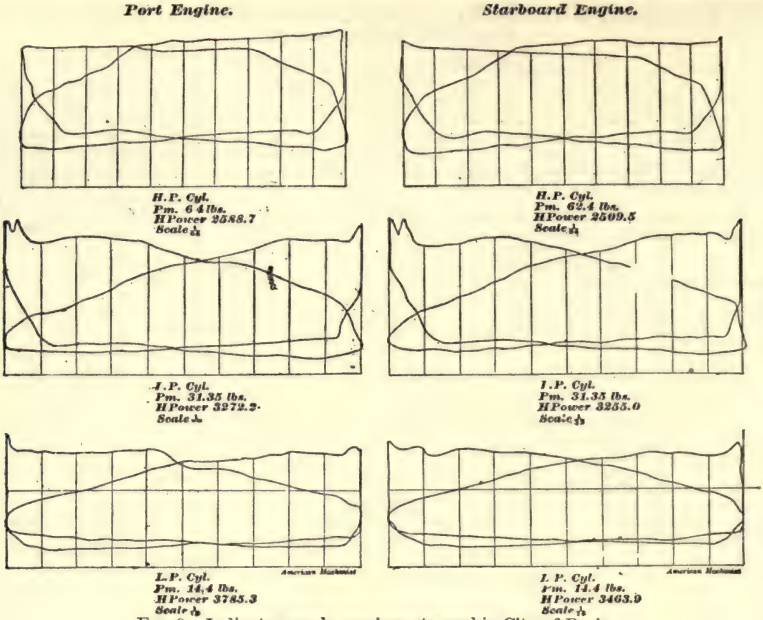


FIG. 9.—Indicator cards, engines steamship City of Paris.

TABLE VII.—*Steamship City of Paris.*

Diameter of cylinder, h.-p.	45″
" " i. p.	71″
" " l. p.	113″
Area of grate surface	1,294 sq. ft.
" heating surface	50,250 "
" cooling surface	33,000 "

RATIOS.

Heating to grate surface	38·8 : 1
" condenser surface	1·52 : 1
Stroke (common)	60″

Ratios of cylinders:

H.-P.	I. P.	L. P.
1	2·489	6·304
	1	2·53
	2·489 : 2·53 :: 1 : 1·017	

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	Port.	Starboard.
Steam	148	148
Revolutions	87	86·5
Vacuum	26	26
Cut-off, h. p.	full	full
" i. p.	"	"
" l. p.	"	"
Mean pressure, h. p.	64	62·4
" " i. p.	31·35	31·35
" " l. p.	14·4	14·4
Indicated horse-power, h. p.	2,588·7	2,509·5
" " i. p.	3,272·2	3,255
" " l. p.	3,785·3	3,763·9
Total indicated horse-power for one engine	9,646·2	9,528·4
" " " two engines	....	19,174·6
Temperature of feed-water	....	119°
" sea-water	....	54°
Lbs. of water per i. h.-p., h. p.	11·42	*10·25
" " " " i. p.	13·1	13·87
" " " " l. p.	11·74	12·42
I. h.-p. per revolution	110·84	110·1
I. h.-p. per sq. ft. of grate	....	14·82
" " of heating surface, $\frac{1}{2{\cdot}62}$, or 2·62 sq. ft. h. s. per i. h.-p.		
" " of condensing surface, $\frac{1}{1{\cdot}72}$, or 1·72 sq. ft. c. s. per i. h.-p.		
Clearance, calculated from compression-curve, h. p., 17·9; i. p., 8·25; l. p., 7·4 per cent.		
Number of cub. ft. swept per min. per i. h.-p. by l.-p. piston	6·28	6·32
Mean pressures referred to l.-p. piston	36·89	36·69

* From indicator cards. No allowance for heat into work or condensation.

Tests of Ferry-boat Engines.—For many years the prevailing type of ferry-boat on the large rivers of the United States, especially in the eastern portion, where the depth of water is sufficient, has been a double-ended paddle-wheel boat, with the wheels of large diameter placed at or near the middle of the length of the hull, and driven by the American type of beam-engine. The service demanded of a New York ferry-boat calls for some peculiar features of construction. The weight of the loads carried, both in passengers and teams, as well as the strain caused by the ice, and the danger of collision, all call for a hull of great strength and rigidity. Beyond this, the vessel must have great stability to resist burying by the head as well as heeling. She must be able to make headway in floating ice, and should attain a speed of about 12 miles an hour in service. Quite recently a departure from the paddle-wheel boat has been made in the ferry between New York and Hoboken, which has proved so successful that other ferry companies are preparing to follow the example. The first ferry-boat of this type on the Hoboken ferry, called the Bergen, is described at length in a paper by E. A. Stevens and Prof. J. E. Denton, in *Trans. A. S. M. E.*, vol. x. The chief feature of novelty in the Bergen is the use of two screws, each of 8 ft. diam., and 8·9 ft. pitch, one at the bow and one at the stern, on a single shaft running the entire length of the boat, driven by a triple expansion engine.

TABLE VIII.—*Showing a Comparison as to Capacity between the Bergen, Orange, and Moonachie, of the Hoboken Ferry, built respectively in 1889, 1887, and 1877.*

	Bergen.	Orange.	Moonachie.
Built	1889	1887	1877
Hull	Steel	Steel	Wood
Engine, type	Triple expan. propeller	Low-pressure beam	Low-pressure beam
Size	18½″, 27″, and 42″ × 2′	46″ × 10′	44″ × 10′
Safety-valve pressure ... lbs. per sq. in.	160	45	30
Length, l. w. l. ... ft.	200	217	200
Beam, l. w. l. ... ft.	32·16	32	32
Beam, over guards ... ft.	62	62	62
Draft, hull to base-line	8·83	7·66	8
Displacement to l. w. l. ... tons	560	655	550
" per in. at l. w. l.	12·6	....	....
Space available for passengers ... sq. ft.	4,330	3,791	3,335
" " for number of seats	296	254	236
" " for teams ... sq. ft.	3,448	3,940	3,380

In the paper referred to Prof. Denton describes at length experiments made to determine the relative economy of the Bergen as compared with the best type of paddle-wheel ferry-boat having the common style of overhead beam-engine, a jet condenser, and drop-return flue-boilers. The paddle-boat selected for this purpose was the Orange, one of a pair of steel boats designed in 1887 by Mr. Francis B. Stevens, and representing the best modern example of its class of ferry-boats. The programme carried out was as follows:

I. The steam consumption, boiler evaporation, horse-power, and speed were determined for each boat during 14 hours of regular ferry service.

II. Each was run to Newburgh and return, a distance of 120 miles, without stoppage, and the steam consumption per horse-power determined at the maximum capacity of the boilers. Also the evaporative economy of the boilers, starting with new wood-fires, was determined during an interval of 14 hours, and the speed was measured by an estimate of the probable velocity of tides, and a log whose correction coefficient was approximately known.

III. The speed of the Bergen was determined at the maximum horse-power for which the engines were designed, by opposite runs over a 1-mile course, after allowing the boiler-pressure to accumulate above the average pressure which the boilers can maintain for more than a few minutes.

IV. One of the screws of the Bergen was removed, and the power and speed determined by runs over a 2-mile course, first with the engine-screw pushing and then with it pulling the boat at equal speeds of revolution of the engine.

TABLE IX.—*General Summary of Experiments of Ferry-boats Orange and Bergen.*

	ORANGE.	BERGEN.		
		High.	Interm.	Low.
ENGINE.				
Diameter of cylinder ... in.	46 in.	18½″	27″	42
Stroke ... ft.	10 ft.	2 ft.	2 ft.	2 ft.
Cut-off	0·45	⅝	⅝	⅝
Clearance	3·7%	16%	10·7%	11·3%
Total expansion	2·1	....	9	....
Area of admission-ports, per cent of piston	......	12%	12½%	11
BOILERS.				
Total heating surface ... sq. ft.	3,049		3,462	
Superheating surface ... "	0		0	
Grate area ... "	80		81	
Ratio of grate to heating surface	38		43	

TABLE IX.—*General Summary of Experiments of Ferry-boats Orange and Bergen (continued).*

	120-mile run.	Ferry service.	120-mile run.	Ferry service.
PRESSURES.				
Average boiler pressure......lbs. above atmosphere	17	32	114	140
" pressure during admission ...... " " "	16	31	105	100
" back pressure...... " " "	......	4¼	......	3
" vacuum pressure......	......	27 in.	......	27 in.
TEMPERATURES.				
Feed-water......	93°	......	118°	......
Uptake......	500°	......	750°	......
Top of stack......	435°	......	650°	......
INDICATED HORSE-POWER.				
I. h.-p., including all pumps......	490	810	......	......
" not including pumps......	......	......	665	650
" feed-pump......	......	......	9	......
" circulating-pump......	......	......	3	......
" bilge-pump......	......	....	1¼	......
TOTAL WEIGHTS.				
Bituminous coal per hour......lbs.	*1,560	......	*1,580	......
Percentage of ashes......	11%	......	7·87%	......
Feed-water per hour for all purposes......	13,487	......	14,511	......
" " for pumps, etc......	......	.....	2,358	......
" " for steering engines......lbs.	......	150	......	150
EFFICIENCY OF BOILERS.				
Evaporation at actual pressure and temperature of feed per lb. of coal......	8·65	......	9·2	8·42
Evaporation from and at 212° per lb. of combustible......	11	......	11·40	......
EFFICIENCY OF ENGINE.				
Water for all purposes per hour per i. h.-p......	27	25	21·8	22·9
Water, main engines only, per hour per i. h.-p......	......	......	18·3	......
Water, feed, and circulating pumps, etc., per hour per i. h.-p......	......	......	160	130
Theoretical water per hour per i. h.-p......	......	......	Condensing	Non-condensing
Calculated from card......	20	......	13·2	......

TABLE X.—*Summary of Speed Determinations of Bergen.*

CONDITIONS.	Revolutions per min.	Horse-power.	Observed still-water or true speed, statute miles per hour.	Slip per centum.	ESTIMATED SPEEDS. From a speed at 145 revs by law of cubes.	From augmented surface. $V = \sqrt[3]{\frac{21,200 \text{ H.-P.}}{\text{Aug. surf.}}}$	From apparent slip.
	1	2	3	4	5	6	7
Two screws in use....	142	662	11·9	16·4	12·37	14·19	11·8
" " "	145	700	12·62	12·6	12·60	14·57	13·4
" " "	162	1,007	14·6	11	14·30	16·13	16·2
" " "	114	334	10·5	10·?	10·50	11·27	11·6
" " "	71	97	6·4	10·?	6	7·45	7·8
One screw at stern...	145	458	11·96	18·2	11·96	12·5	12·7
" " " ...	163	684	13·42	17·7	13·67	14·32	14·4
" " " ...	83	93	6·98	16	7·30	7·36	7·8
One screw at bow....	145	461	11·28	†22·3	.....	11·99	12

TABLE XI.—*Speed of Paddle-wheel Boat Orange.*

Revolutions.	Horse-power.	Observed true speed, statute miles.	Speed calculated from augmented surface. $V = \sqrt[3]{\frac{18,000 \text{ H.-P.}}{\text{Aug. surf.}}}$	Apparent slip, percentage.	Speed estimated by law of cubes, statute miles.
22·9	490	11¼	12·1	26	....
24·6	642	....	....	26	12·6

Average pitch for pushing side of blade......	8·911
Average pitch for pulling side of blade......	8·920
Projected area of blades in per cent of disk area......	53·1
Area of boss......	3·5

Long-Service Trial of Bergen versus Orange.—During October, 1888, the Orange was operated steadily, on the Barclay Street route, 339 hours, averaging about 15 hours daily.

* These amounts are estimated from the feed-water consumed, by use of the figures for evaporation per lb. of coal, as determined from the boiler-tests.

† Assumed to be 18 per cent for calculation of column 7.

Her coal consumption, including fuel for banking and starting fires, was 1,027 lbs. per hour. During June, 1889, the Bergen was operated the same number of hours, and upon the same time-table as the Orange. Her coal consumption was 936 lbs. per hour. The coal used by the Bergen was, therefore, about 9 per cent less than that used by the Orange. Some of the conditions of this trial were unfavorable to the Bergen.

Possible Maximum Economy of a Screw-boat versus Paddle-boat.—Assuming that three fourths of the pump's, etc., consumption, which was very excessive in the Bergen, can be saved, and that the full advantages of the triple expansive system can be made available by maintaining 150 lbs. pressure, the steam consumption per hour per horse-power of all the machinery may be safely estimated at 18 lbs. This would make the consumption relative to the Orange for 14-mile speeds, as $910 \times 18 = 16,380$ to 810×26, or as 78 to 100, making a margin of 22 per cent in fuel. The same size of engine as in the Bergen could command 1,000 horse-power with about two thirds of the present boiler capacity. This will make the boilers of a screw-boat weigh about the same as those of the Orange.

The total weight of the screw-boat will be about 220,000 lbs. lighter, 80,000 lbs. of which is due to absence of paddle-wheels and 140,000 lbs. to difference of weight of hull. The difference of first cost due this difference of weight plus the above saving of coal, must be put against the extra repairs of the machinery and extra attendance of the screw-boat. Prolonged experience with the new type of boat can alone settle exactly the balance in its favor; but that there will be a considerable balance financially there need be little doubt, while the advantages of better accommodation, greater attractiveness, and greater control in service are incontestable.

After a year's experience with the Bergen, during which she amply justified the expectations of her builders and owners, another screw-boat, the Bremen, was built, and was put in service in December, 1891. Instead of a triple-expansion engine, the Bremen was fitted with two independent compound engines, each 20 and 36 in. diameter of cylinder and 2 ft. 4 in. stroke, the cranks in each engine being opposite, or at 180°, and the line of cranks of the two engines being at right angles to each other. Each engine is therefore perfectly balanced, and the crank-shaft, having four cranks at 90°, thus receives a very uniform turning effort, which diminishes the tendency to vibration of the boat, which is a very objectionable feature in most ferry-boats. On the trial trip the Bremen made an average speed of 13½ miles per hour. The steam consumption per indicated horse-power of the engines was 20·64 lbs. per hour. The following are the principal dimensions of the boat and its power equipment: Length of load water-line, 217 ft.; beam (load water-line), 35 ft.; beam over guards, 62 ft.; displacement (load water-line), 1,900,000 lbs.: number of seats, 464; length of boiler, 21 ft.; diameter of boiler, 9 ft.; number of boilers, 2; grate area, 91 sq. ft.; ratio of grate area to total heating surface, 36·6; diameter of cylinders, 2 of 20 in., 2 of 36 in.; stroke, 2 ft. 4 in.; safety-valve pressure, 120 lbs.; diameter of propellers, 8 ft. 6 in.; pitch of propellers, 11 ft.

The Efficiency of Screw-Propellers.—In a paper presented at the Washington meeting of the American Association for the Advancement of Science, 1891, Prof. J. E. Denton points out that the statement to be found in some standard treatises and text-books to the effect that the screw-propeller realizes but about 38 per cent useful effect out of a given indicated horse-power, is inconsistent with modern data regarding screw propulsion. This was one of the generalizations of Froude, the great expert, regarding marine propulsion, and was arrived at as follows: Out of a given indicated horse-power it was assumed: First, that 15½ per cent was lost through the "stern resistance" caused by the presence of the propeller at the stern interfering with the support of the latter by the following wave or the replacement wave of Scott Russell's theory. This was determined by towing models with a dynamometer. first without a screw and second with a screw, detached from the model, but made to follow close behind it. Second, about 4 per cent was estimated to be lost by the friction of the screw in the water. There is no very accurate knowledge of this element of loss to-day. Third, 13 per cent was assumed to be consumed in the friction of the engine unloaded, and 13 per cent more was assumed to be expended by the extra friction due to the load on the engine. Fifth, about 7 per cent was assumed to be consumed by the air-pump. The only authority for this was a statement by Tredgold. Sixth, the slip was assumed at 10 per cent. The total loss, therefore, foots up about 62 per cent, leaving about 38 per cent of the indicated power available to propel the hull. Dynamometer tests have always shown considerably higher efficiency than this, affording from 65 to 70 per cent, as shown in the following table. Also, computations of efficiency based on an estimate of the resistance of the hull by Rankine's augmented surface theory, on a number of American boats, indicate an efficiency of about 67 per cent for both screws and paddles. Rankine's formula for resistance is considered to err on the side of giving too low a horse-power for a given speed, so that efficiencies calculated by it are too low, if in error. The air-pump resistance of marine engines is now known to be only about 1½ per cent of the indicated horse-power. The friction of the engine unloaded has been found to be as low as 8 per cent. A revisal of Froude's estimate with these modifications might therefore show nearly 60 per cent efficiency. Rankine's estimate of the efficiency of the Warrior, a screw vessel in the British Navy, made the stern resistance 7 per cent, the slip 9 per cent, the screw friction 2 per cent, and the friction of engine loaded, including air-pump, 22 per cent; making the total loss 40 per cent, and the efficiency 60 per cent.

The first line of the following table applies to the steamer Admiral, whose efficiency Rankine also estimated at 60 per cent. The remaining boats for which the hull resistance is estimated ply on the Hudson River, the Orange and Bergen being ferry-boats, the others well-known passenger-boats:

TABLE XII.—*Efficiency of Screws and Paddles.*

NAME.	Date.	Length, ft.	Breadth, ft.	Draft.	Displacement, gross tons.	Wetted surface, sq. ft.	Coefficient of augmentation.	Augmented surface.	Indicated horse-power.	Speed in knots.	Per cent of slip.	Per cent of indicated power available to propel hull.
FEATHERING PADDLES.												
Admiral	1860	....	..	......	....	......	....	8,560	744	12	22	·60
City of Fall River	1884	260	42	12′	2,350	11,000	1·26	13,804	1,616	14	20	·68
RADIAL PADDLES.												
Mary Powell	1879	286	33½	6′	857	7,377	1·08	7,981	1,600	16·65	16½	·68
Sylvan Dell	1880	178	25	4′ 10″	305	3,737	1·20	4,495	686	15·3	20½	·68
Rhode Island	1877	325	45	10′	2,513	13,695	1·18	16,000	2,300	15	17	·69
Orange	1890	211	32	7′ 8″	....	5,571	1·32	7,347	490	10·4	27	·55
SINGLE SCREW.												
Homer Ramsdell	1889	211	32	11′	611	7,365	1·21	8,839	1,030	13·67	11	·68
City of Kingston	1886	250	34	10′	700	8,260	1·18	9,736	1,120	14	15	·69
Bergen, using one screw at stern	1890	200	32	8′ 10″	....	5,788	1·30	5,788	7,524	10·5	18	·60

In the above examples the power to propel the hull is estimated from the augmented surface. In the following cases the power to propel the hull was measured by a dynamometer at the thrust-block of the screw-shaft.

NAME.	Date.	Length, ft.	Breadth, ft.	Draft.	Displacement, gross tons.	Wetted surface, sq. ft.	Coefficient of augmentation.	Augmented surface.	Indicated horse-power.	Speed in knots.	Per cent of slip.	Per cent of indicated power available to propel hull.
SINGLE SCREWS.												
Rattler	1840	176½	32′ 8″	......	888	......	....	......	335	19·2	....	·70
Vlaardinger	1890	70	14′ 9″	5′	69	......	....	......	170	10·5	13·4	·69
Yarrow's torpedo-boat	1883	100	12′ 6″	......	40	......	....	......	230	15	....	·65

Performances of Atlantic Steamers.—The remarkable Atlantic passages of 1891 were made by the Majestic and Teutonic, of the White Star line. The Majestic made the westward trip several times under 6 days, the mean speeds varying from 19·58 to 20·11 knots. In February, 1892, she made an average run of 20·41 miles per hour, the highest accomplished, but the longer route being taken, the Teutonic's record for quick passage was not broken. The Teutonic steamed from Queenstown to New York thrice in less than 6 days, and made the return trip three times within the same period. Of the 12 best passages made by these steamers in 1891, the mean time is but 5 days 21 hours and 5 minutes. The following table shows the details of the quickest passages made by the above vessels, and by the City of Paris and City of New York, of the Inman and International lines:

Queenstown to New York.

STEAMER.	Date.	Passage. d. h. m.	Miles steamed.	Speed in knots.
Teutonic	August, 1891.	5 16 31	2,778	20·35 *
Majestic	July, 1891.	5 18 8	2,777	20·11 †
City of Paris	August, 1889.	5 19 18	2,788	20·01 ‡
City of New York	October, 1890.	5 21 19	2,775	19·63 #

New York to Queenstown.

STEAMER.	Date.	Passage. d. h. m.	Miles steamed.	Speed in knots.
Teutonic ‖	October, 1891.	5 21 3	2,790	19·79 △
City of Paris	December, 1889.	5 22 50	2,784	19·49
City of New York	September, 1891.	5 22 50	2,782	19·44
Majestic	" 1890.	5 23 16	2,809	19·61

The Fürst Bismarck, of the Hamburg-American line, made the run from Southampton to New York (3,086 miles), in May, 1891, in 6 days 14 hours 15 minutes—average speed, 19·5 knots; and the return to Southampton (3,114 miles) in 6 days 13 hours 25 minutes—average speed, 19·78 knots.

The accompanying table, from *Engineering*, shows the dimensions and performances of some of the most notable Atlantic steamers built from 1874 to 1891, in comparison with the Great Eastern, built in 1858:

* Daily runs: 460, 496, 505, 510, 517, 290 miles.
† Daily runs: 470, 501, 497, 501, 491, 317 miles.
‡ Daily runs: 432, 493, 502, 506, 509, 346 miles.
# Daily runs: 437, 460, 498, 495, 491, 394 miles.
‖ In November, 1891, the Teutonic came home in 5 d. 21 hrs. 45 min., but the distance traveled gave her a mean speed of 19·85 knots.
△ Daily runs: 483, 468, 468, 460, 440, 457, 14 miles.

Dimensions, etc., of some Notable Atlantic Steamers.

STEAMER'S NAME.	Builders.	Date.	DIMENSIONS. Length.	Breadth.		Depth.		PROPORTION OF LENGTH To beam.	To depth.	Draft.		Displacement.	Gross tonnage.	CYLINDERS. Diameter in inches.	Stroke.	BOILERS. Heating surface.	Grate area.	Working pressure.	Indicated horse-power.	Speed on trial.
			Ft.	Ft.	In.	Ft.	In.			Ft.	In.				In.					
Great Eastern...	Mr. Scott Russell....	1858	680	82	6	58	2	8·23	11·7	25	6	27,000	24,360	....	..	......	....	....	7,650	14·50
Britannic........	Messrs. Harland & Wolff.	1874	455	46	0	34	0	9·89	13·38	23	7	8,500	5,004	Two 48 in., two 83 in.	60	......	....	70	5,500	16
Arizona..........	Fairfield Company..	1879	450	45	2	37¼	0	9·96	12	18	9	......	5,147	One 62 in., two 90 in.	66	......	....	90	6,300	17
Servia...........	Messrs. Thomson....	1881	515	52	0	40¼	0	9·90	12·62	23	3¼	9,900	7,392	One 72 in., two 100 in.	78	27,483	1,014	90	10,300	16·9
Alaska...........	Fairfield Company..	1881	500	50	0	39	7	10	12·63	21	0	......	6,932	One 68 in., two 100 in.	72	......	....	100	10,500	18
City of Rome....	Barrow Company...	1881	546	52	0	38¼	0	10·5	9·29	21	6	11,230	8,141	Three 46 in., three 86 in.	72	29,286	1,398	90	11,890	18·23
Aurania.........	Messrs. Thomson....	1882	470	57	0	39	0	8·24	12·05	......		......	7,269	One 68 in., two 91 in.	72	23,284	1,001	90	8,500	17¾
Oregon..........	Fairfield Company..	1883	500	54	0	39¼	0	9·25	12·57	23	8	......	7,375	One 70 in., two 104 in.	72	......	....	110	7,375	18·3
America.........	Messrs. Thomson....	1884	432	51	0	37¼	0	8·47	11·52	26	7	9,300*	6,500	One 63 in., two 91 in.	66	22,750	882	95	7,354	17·8
Umbria..........	Fairfield Company..	1884	501·6	57·2	0	38·2	0	8·76	13·13	......		10,500	7,718	One 71 in., two 105 in.	72	38,817	1,606	110	14,321	19
Lahn............	" "	1887	465	49	0	36¼	0	9·48	12·83	22	0	7,700	5,661	Two 32¼ in., one 68 in., two 85 in.	72	......	....	150	9,500	18·64
City of Paris.....	Messrs. Thomson....	1888	560	63	0	43	0	8·89	13·02	24	6	13,000	10,499	Two 45 in., two 71 in., two 113 in.	60	50,265	1,293†	150	20,605	21·8
Augusta Victoria.	Vulcan Co., Stettin..	1889	480	56	0	38	0	8·6	11·65	22	9	9,500	7,661	Two $41\frac{5}{16}$ in., two $66\frac{15}{16}$ in., two $106\frac{5}{16}$ in.	63	36,000	1,120	150	14,110	18·31
Columbia........	Messrs. Laird Bros..	1889	480	56	0	38	0	8·6	11·65	22	9	9,500	7,578	Two 41 in., two 66 in., two 101 in.	66	34,916	1,226	150	13,680	19·15
Teutonic.........	Messrs. Harland & Wolff.	1890	582	57¼	0	39	4	10·1	9·8	26	0	12,000	9,686	Two 43 in., two 68 in., two 110 in.	60	40,072	1,154	180	18,000	21
Normannia......	Fairfield Company..	1890	520	57¼	0	38	0	9·08	13·7	22	0	10,500	8,716	Two 40 in., two 67 in., two 106 in.	66	46,490	1,452	160	16,352	19·34
Spree............	Vulcan Co., Stettin..	1890	485	52	0	38	0	9·33	12·8	22	0	8,900	6,963	Two 38 in., one 75 in., two 100 in.	72	......	....	165	13,000	19·6
Fürst Bismarck .	" " "	1891	502¼	57¼	0	38	0	8·73	13·2	22	6	10,200	8,000	Two 43⅝ in., two 67 in., two 106¼ in.	63	47,000	1,450	157	16,412	20·7

The Etruria is practically the same as the Umbria; the City of Paris and City of New York are alike; so also are the Teutonic and Majestic, and the Spree and Havel. The differences in the case of each pair are not important.

* On trial.

† The introduction of Howden's system of forced draft has resulted in the shortening of the fire-bars by 13 in., bringing the fire-grate area to 1,026 sq. ft. The results are under the closed stoke-hold system of forced draft.

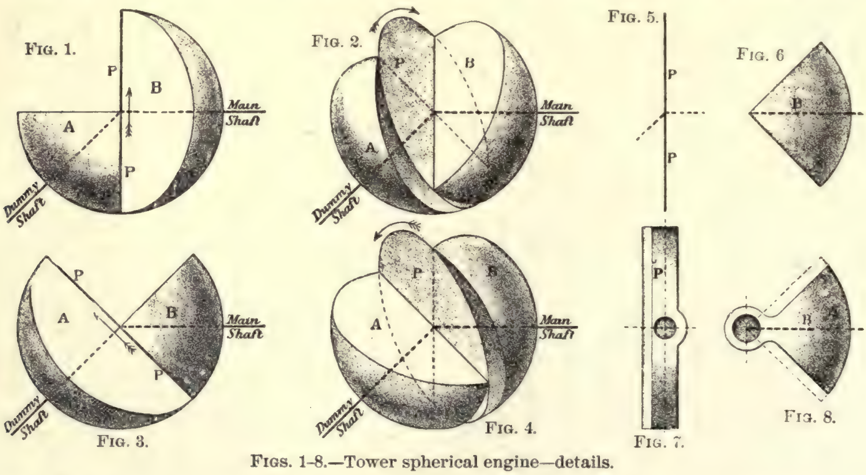
As to fast vessels of the future, none of the builders of Atlantic steamers entertain any belief in the probability of electricity or any other motive power superseding steam in the propulsion of ships. There is no doubt, however, that if electricity could be generated by compact carbon or gas batteries of the same weight as is required for the boilers and engines in present-day racers there would be a great advantage, for the efficiency of the electric motor is very much higher than that of the steam-engine; but for the present, steam is the only source of power for ship propulsion. The principal aim in the future will be to so design boilers and machinery as to give the best results for weight, and chemistry may help the marine engineer by producing an alloy which, reducing the weight, will allow of a higher piston-speed. There is not much chance of any material change in propellers. The main idea is to make them of such a size as to enable the engines to revolve at their designed speed.

If the ship of the future, then, is to be of greater size—and the past certainly points in this direction—there is no alternative but to continue increasing the power of the engines. Taking the case of the City of Paris, which at her maximum speed of 21 knots required over 20,000 indicated horse-power, we find that she would require for 23½ knots speed 28,000 indicated horse-power, and for 25 knots 34,000 indicated horse-power. For an increase in speed of 20 per cent there is, therefore, needed an addition of 70 per cent to the power.

As to speed, there is really no insurmountable difficulty in attaining 40 knots, but this would require something like 160,000 indicated horse-power, 70 boilers to generate the steam for the engines, and these would burn considerably more than 2,000 tons of coal per day. The experience of the past suggests these figures. Some idea may be formed as to the size of vessel necessary for this machinery. The question is one of finance, and it might need a company of millionaires to own and run a fleet of such vessels. In ten years the speed has increased from 16 to 20 knots, and in the same time the indicated horse-power has gone up from 6 000 to 18,000, while the size of the ship has only been doubled. To attain this result the ship of to-day burns 1,900 tons of coal in six days, whereas ten years ago 600 tons only were burned in 7½ days. (See *Engineering* for Dec. 4, 1891, for graphic diagrams and other information, and for June 19, 1891, for performances of Atlantic steamers during the season of 1890.)

ENGINES, STEAM ROTARY. *The Tower Spherical Engine.*—The construction of this engine is described in detail, with illustrations, in *Proc. Inst. M. E.*, 1885. Space will not admit of the complete description being given here, but the following abstract gives a clear idea of its geometrical principles. The spherical engine consists, as its name implies, of a system of parts contained within a sphere, and so united as to enable them under the action of steam-pressure to impart rotary motion to a shaft. It is an engine that seems peculiarly suitable for high-speed direct driving. It is the invention of Mr. Beauchamp Tower, to whom the idea of its construction originally occurred through watching the relative motions of the three parts composing a universal joint.

Geometrical Construction: Considered geometrically, the three elementary moving parts of which the engine is composed are, a pair of quarter-spheres A and B, with a circular disk P of infinitesimal thickness interposed between them, the diameter of the disk being the same as that of the sphere of which they are sectors. The straight edges of the sectors are hinged on opposite sides of the disk along diameters at right angles to each other, as illustrated in the diagram, Fig. 1, in which the disk P, being seen edgewise, appears as a straight edge



FIGS. 1-8.—Tower spherical engine—details.

only. Each sector rotates upon an axis of its own, upon which it is fixed symmetrically; the two axes lie in the same plane, which is the plane of the paper in Fig. 1, and they meet in the center of the disk P at an angle of 135°. The two sections A and B thus correspond with the two bows of an ordinary universal joint, and the disk P answers to the cross-piece connecting the bows. Starting from the position shown in Fig. 1, and supposing the direction

of rotation to be such that the lower portion of the right-hand sector is approaching toward the eye while its upper portion is receding, as indicated by the arrows, the relative positions after three successive eighths of a revolution will be as shown in Figs. 2, 3, 4.

Considering first the relative motions of the left-hand sector A and the disk P, it is seen that in Fig. 1 this sector is in close contact throughout with the lower half of the disk; while between the sector and the upper half of the disk there is a cavity equal to a quarter sphere. In rotating from Fig. 1 to Fig. 2, a cavity is opening between the sector A and the lower half of the disk P, while the upper cavity is closing to the same extent. In Fig. 3 the opening and closing cavities are of equal size, each being one-eighth of a sphere. In Fig. 4 the opening cavity has become still larger and the closing cavity still smaller; and after the next eighth of a revolution the opening cavity will be fully open and the closing cavity entirely closed, the relative positions thus being again as in Fig. 1, except that each sector is now reversed end for end, having completed half a revolution upon its axis. A similar opening and closing of cavities has been progressing simultaneously between the disk P and the right-hand sector B. Throughout each revolution there are consequently two cavities simultaneously in process of opening and two others in process of closing, all four alike changing at the same mean rate of increase and diminution. If, therefore, the disk with its pair of sectors be incased within a hollow sphere of the same diameter, and if steam be admitted into the two opening cavities and exhausted from the two that are closing, continuous rotary motion will be produced, driving the two shafts represented by the axis of the two sectors. When one of the two opening chambers is only just commencing to open, the other is half open; so that while the one is making no effort the other is in the position of best effort, and the mean effort of the engine is as uniform as that of a two-cylinder engine with cranks at right angles. It is also evident, as an interesting feature in the system, that, although the whole of the engine may be said to be contained within the sphere itself, yet the capacity of the engine is no other than the full capacity of the sphere itself, inasmuch as four quarters of the sphere are filled and emptied in one revolution.

Construction of Engine: The names adopted for the three principal working parts are as follows: The intermediate vibrating disk P is called the piston, and the sectors B and A on the ends of the main and dummy shafts are called respectively the main and dummy blades. The piston, replacing the geometrical disk of infinitesimal thickness, has to be made of substantial thickness, and fitted effectively with a steam-tight packing all round its edge. The hinge union along the straight edge of each blade has to be made a cylinder of finite diameter instead of a geometrical line; and the junction must be so contrived as to make a substantial hinge-joint that will stand the wear and tear consequent on the rapid oscillation of the parts.

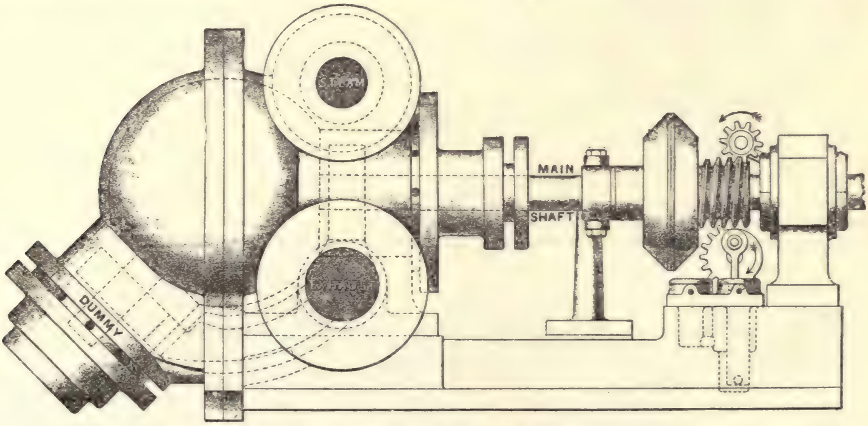


FIG. 9.—Tower spherical engine.

Thickness is obtained for the piston by deducting hlfa its thickness from each of the two flat sides of each blade—that is, the disk P and sector B, originally depicted as in Figs. 5 and 6, are altered to the forms shown in Figs. 7 and 8. Two cylindrical ribs, having their axes in the middle plane of the piston, are formed on its opposite faces, and along diameters at right angles to each other, Fig. 7, and into these are let circular lugs with eyes, formed on the straight edges of the two blades, Fig. 8, which are thereby hinged to the piston in the manner of an ordinary hinge, having a lug and socket with a pin through. The effect of these departures from the elementary geometrical form already described is to reduce the capacity of the engine by the amount of the cubic measurement of the hinges. An external view of the engine is shown in Fig. 9. The engine is used for the direct driving of dynamos, and runs from 600 to 1,100 revolutions per min. A test of a 10-in. engine running 600 revolutions per min. gave a water consumption of 37 lbs. per brake horse-power per hour.

Compound Steam Turbine.—Mr. Charles A. Parsons describes, in the *Proc. Inst. M. E.*, October, 1888, a compound steam turbine of his invention, as follows: The compound steam turbine T (Figs. 10 and 11) consists of two series of parallel-flow or Jonval turbines, set one

after the other on the same spindle S, so that each turbine takes steam from the one before and passes it on to the one following. In this way the steam entering all round the spindle

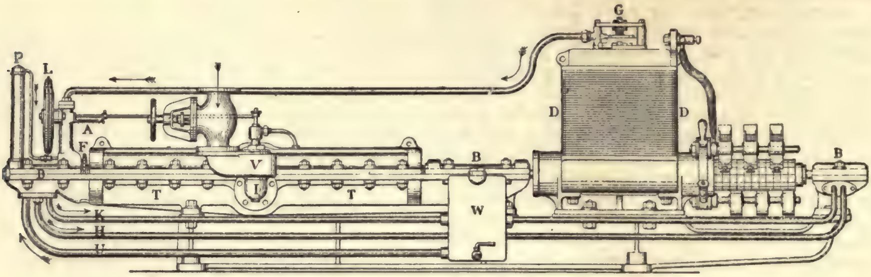


FIG. 10.—Parson's compound steam turbine.

from the central inlet I, Fig. 10, passes right and left through the whole of each series of turbines to the exhaust E at each end. The steam expands as it loses pressure at each turbine;

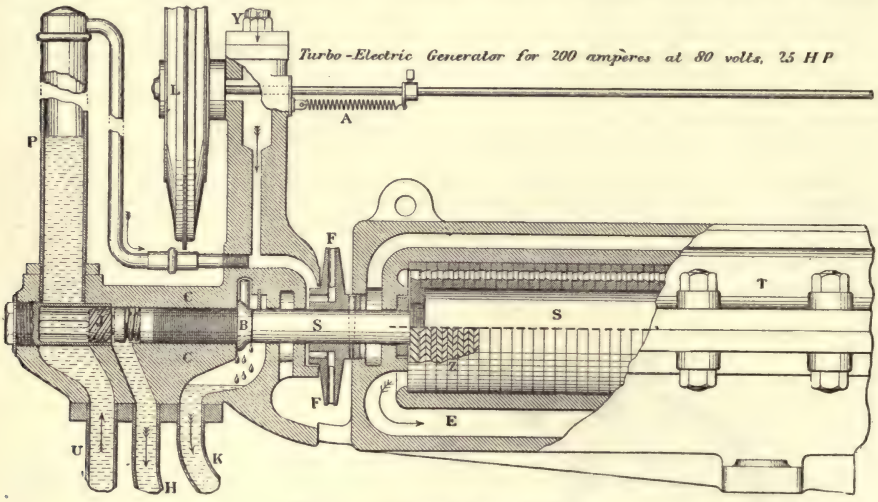


FIG. 11.—Compound steam turbine.

and by successive steps the turbines are increased in size or area of passage-way, so as to accommodate the increase of volume, and to maintain a suitable distribution of pressure and

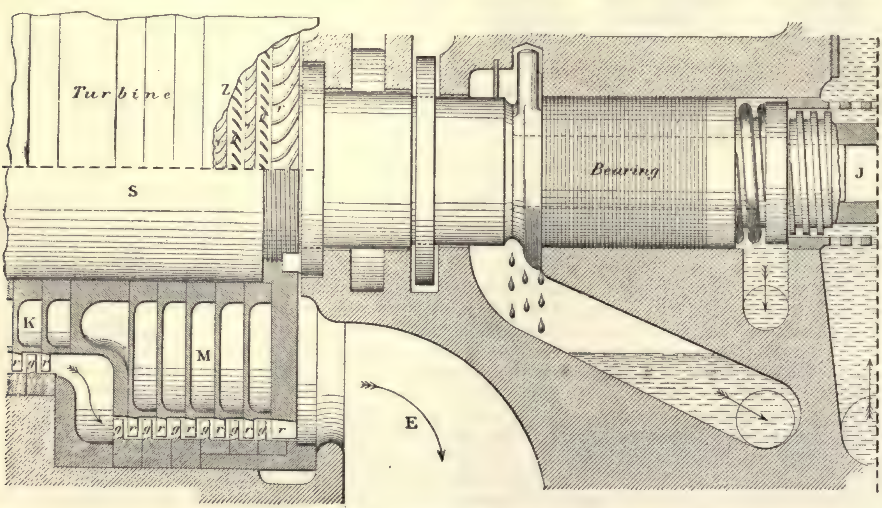


FIG. 12.—Compound steam turbine.

velocity throughout the whole series of turbines. The areas of the successive turbines are so arranged that the velocity of the flow of steam shall bear throughout the series about the same ratio to the speed of the blades; and as far as possible this ratio of velocity is so fixed as to give each turbine of the series its maximum efficiency. The two equal series of turbines on each side of the central steam-inlet *I* balance each other as regards any end pressure on the spindle of the motor, and thus remove any tendency to undue wear on the collars of the bearings *B*. The turbines are constructed of alternate revolving and stationary rings of blades. The revolving blades *r*, Fig. 12, are cut with right or left hand obliquity on the outside of a series of brass rings, which are threaded upon the horizontal steel driving-spindle *s*, and secured upon it by feathers; the end rings form nuts, which are screwed upon the spindle and hold the rest of the rings upon it. The stationary or guide blades *g* are cut with opposite obliquity on the inside of another series of larger brass rings, which are cut in halves, and are held in the top and bottom halves of the cylindrical casing by feathers. The set of blades on each revolving ring runs between a pair of sets of the stationary or guide blades. The passage between the blades in the alternating rings form a longitudinal series of zigzag channels when the machine is standing still.

A 50-horse-power turbo-generator has been constructed of the triple-expansion type, using turbines of three different diameters. Including fluid friction, the theoretical efficiency of each turbine in the set is claimed to be about 89 per cent; and the mean efficiency of the whole set is theoretically about 87 per cent of the power which should be given out in the adiabatic expansion of the steam. As the result of tests made when exhausting into the atmosphere and giving off 32,000 watts, it is also stated that the consumption of steam per electrical horse-power per hour has been found to be 42 lbs., with a steam-pressure of 61 lbs. at the inlet. A 6-horse-power generator has run for four years at a speed of 18,000 revolutions per min.

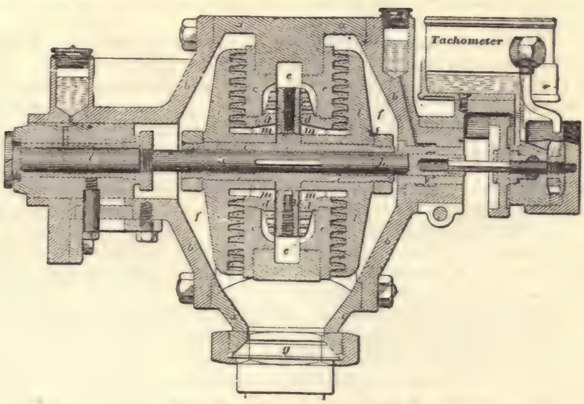


Fig. 13.—Dow steam turbine.

The Dow Steam Turbine is shown in Figs. 13, 14, 15. In Fig. 13 each alternate disk beginning with the second one, is stationary, the others being portions of a revolving plate, the manner of their combination being evident from Fig. 14. In its external appearance the motor is a short cylinder about 9 in. in diameter and 5 in. in length, with two covers having hubs forming bearings for the shaft. The body or shell is a casting, *a a a a*. The covers *b b b b* are through-bolted to the shell. Two disks *c c c c* screw permanently into the wall of the body. On the outward face of each disk are formed six series of stationary guide-plates, as shown in Fig. 13, analogous to those of water turbines, separated by annular spaces concentric with the shaft. The interior of the motor is thus divided into three chambers, of which the central one, *e e*, receives the steam direct from the steam-pipe, and the two outer ones, *f f f f*, receive the exhaust steam which passes out of the motor through the exhaust-pipe *g*. The main shaft *h h* is journaled to the bearing formed in the covers. A sleeve *i i* covers the central part of the shaft, at a sliding fit, being splined to receive two corresponding feathers on the shaft. Two wheels *l l l l* are secured to the sleeve, and it is these wheels which are revolved by the action of the steam, transmitting rotation to the shaft. Upon the inward face of each wheel are formed series of turbines, as shown in Fig. 13, concentric with the shaft and corresponding with and fitting into the annular spaces of the stationary disks; thus the faces of the moving wheels seat (nearly) upon the bottom of the annular spaces of the stationary disks, and the faces of the stationary disks seat (nearly) upon the bottom of the annular spaces of the wheels. In the central chamber, midway between the partitions, is a disk *k*, mounted upon the sleeve; on each side of the disk, distant from it $\frac{17}{1000}$ of an in., is the inner face of the partition, or rather the inner face of an annular face-plate *d*, whose hub screws into

Fig. 14.—Dow steam turbine.

the partition. The disk part of each face-plate stands clear from its partition, and is perforated by three concentric rows of holes, and the inner face of each face-plate is channeled in concentric grooves between the holes, and cross-channeled by radial grooves, starting near the periphery of the face-plate, and running between the perforations. Steam from the boiler enters the central chamber *e e*, passes through the disk-like ports or spaces between the central disk or face-plate on each side of it, as well as through the perforations in the face-plates; flows along the channels in the face-plates to the annular spaces *m m* surrounding the wheel-hub; then right and left toward each wheel; then expands radially outward, through the zigzag of alternate guide-plates and turbines, until it finally exhausts from the circumference of the steam-wheels into the outer chamber, the exhaust-pipe, and the atmosphere.

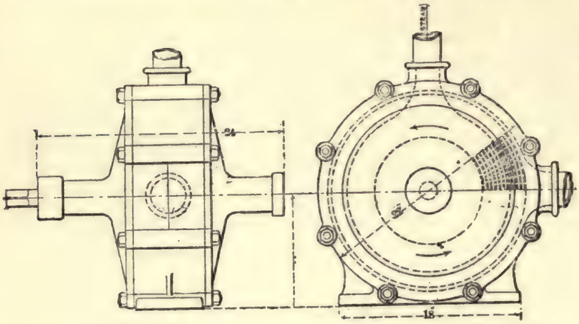


FIG. 15.—Dow steam turbine.

The first practical application of the motor has been on the launching-tubes for the Howell automobile torpedo for the United States Navy (see TORPEDOES). It is used to spin up the fly-wheel of the torpedo, which is one in which the power used for self-propulsion is stored in a rapidly revolving fly-wheel. The dimensions of the wheel are: 13·8 in. in diameter, 6·5 in. in width, and otherwise such that the radius of gyration is 5·57. The energy stored when running at 10,000 revolutions per min. is over 500,000 foot-pounds, and in order to spin it up to the required velocity of 10,000 revolutions per min. in 1 minute's time it requires an expenditure of over 15 horse-power. This expenditure of power commences at zero on starting the wheel, and to average 15 horse-power for the minute the motor must develop power at the final instant at the rate of 30 horse-power. Another application of this motor is to driving a dynamo at the United States Torpedo Station, at Newport R. I. The machine has a capacity of about 150 lights, and is intended for a normal speed of 9,000 to 10,000 revolutions per min.—a figure easily reached.

ENGINES, STEAM, STATIONARY RECIPROCATING. Great progress has been made in stationary steam-engine practice during the last ten years along the lines indicated in the article on steam-engines in Appletons' Cyclopædia of Mechanics. No revolutionary invention has been made during this time, but there has been a steady and rapid development in the direction of stronger and more rigid engines, higher steam-pressures, higher speeds, the substitution of automatic cut-off for throttling-engines, the more general employment of condensers, and the quite general use of compounding. The Corliss engine still holds the first rank as the most economical and generally satisfactory type, and the number of makers of this engine has greatly increased. The changes consist chiefly in higher rotative speeds, 100 revolutions per min. being now not uncommon. A speed of 160 revolutions per min., or 1,120 ft. piston-speed, has been recorded in the Corliss engine (20 in. × 42 in.) in the Trenton Iron-Works. (*Trans. A. S. M. E.*, vol. ii, p. 72.) With the increase of speed there has necessarily come greater constructive stiffness and larger bearing surfaces. The Corliss engine is now usually compounded for large powers, with considerable increase of economy. The two-cylinder cross-compound engine at the Pawtucket (R. I.) Water-Works has shown a water consumption of less than 14 lbs. per hour per horse-power, and the triple-expansion engine at the Narragansett Electric Light Station, Providence, R. I., a water consumption of less than 13 lbs. (See *Trans. A. S. M. E.*, vol. xii.) The high-speed automatic cut-off engines, with shaft or fly-wheel governors, of which the Buckeye and the Straight Line engines, shown at the Centennial Exhibition in 1876, were the first prominent examples, have come very largely into use, especially for small and moderate powers, supplanting the old forms of slow-speed throttling-engines. There has been a continual increase in the speed of these engines, 300 revolutions being quite common for engines of 12-in. stroke, and for longer stroke engines a piston-speed of from 600 to 800 ft. per min. is frequently used. The especial advantages of this form of engine are great compactness, moderate first outlay, low cost of foundations and erection, and great regularity of speed, due to the sensitiveness and efficient action of the governor, which makes them especially well fitted for electric-light purposes. They generally show considerable gain in economy of steam over the throttling-engine, but have not yet equaled the Corliss engine in this respect. Their greater percentages of clearance, and apparently greater tendency to valve leakage, are probably the chief causes of their defects in this particular. Condensation and compounding are now frequently used with these engines, and for electric-lighting purposes a vertical three-cylinder compound, with cranks at 120°, is becoming a favorite form of construction. More common, however, is the two-cylinder tandem compound horizontal engine, either with or without condenser.

The enormous increase in the demand for steam-engines during the past ten years, chiefly due to the introduction of electricity for lighting and for transmission of power, has led to a

great increase in the number of engine-building firms, and to great diversity in the mechanical details of the engines.

I. The Latest Types of Stationary Reciprocating Steam-Engines.—*The Woodbury Engine* is shown in perspective in Fig. 1. Fig. 2 is a vertical section through the cylinder and valve. Fig. 3 is a horizontal section through the steam-chest above the top of the valve. Fig. 4 shows the steam-chest with cover removed, exhibiting the back of the relief-plate and wedge. Fig. 5 is an end view of the relief-plate and wedge. Fig. 6 is an enlarged view of the upper adjusting screw; and Fig. 7 is a back view of the valve.

Referring to Fig. 2, steam-pressure is eliminated from the valve A by the relief-plate B on the back, which is supported against steam-pressure at top and bottom by a forked or double wedge C, whose length is about equal to that of the relief-plate. It is obvious that a longitudinal movement of the wedges inward will force the relief-plate away from the valve, and the outward movement of the wedges will let it down toward the valve. The movement

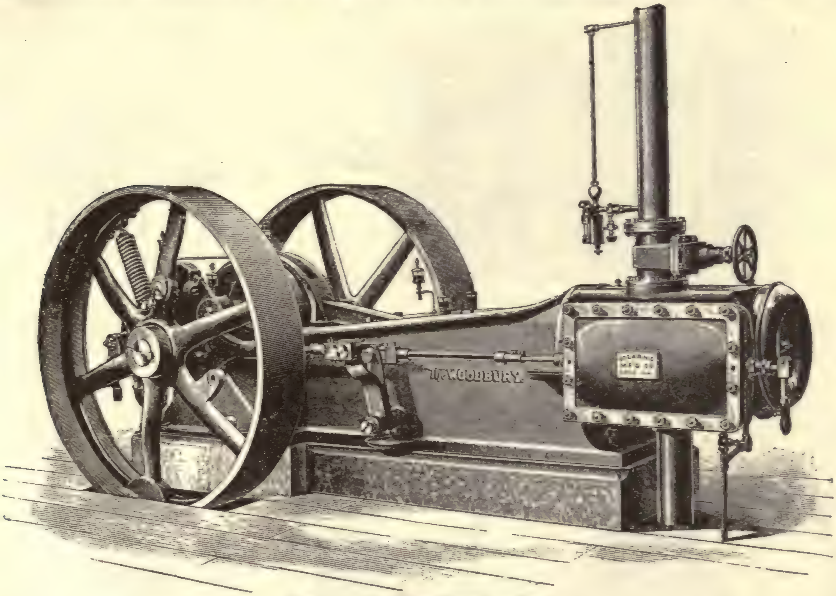


Fig. 1.—The Woodbury engine.

of the wedges, and consequent adjustment of relief-plate, is accomplished by the two adjusting screws $l\ l'$ (Fig. 3), which fit loosely through the cross-piece of wedge and are tapped into the relief-plate. The collars m, which form part of adjusting screws, are notched on their peripheries, as shown in Fig. 6, and a notch n is made on the wedge opposite each screw. The collar has 100 notches, and therefore admits of a definite degree of adjustment. The adjusting screw has 10 threads per in., and the taper of wedges is 1 in. in 10. One notch on the collar, therefore, representing $\frac{1}{100}$ of a turn, moves the wedge lengthwise $\frac{1}{1000}$ of an in., and the relief-plate toward or from the valve $\frac{1}{10000}$ of an in., corresponding to $\frac{1}{20000}$ of an in. on each face of the valve. The passage k at the bottom of the chest allows a circulation of steam under the ledge, insuring equal temperatures for ledges $i\ i'$. The screw D, which is operated from the outside by the handle E, is also used as a means of moving the wedges inward and throwing off the relief-plate; but the plate can not be let down farther than the adjustment allows, as the wedges can not be drawn back farther than the collars m of screws $l\ l'$ (Fig. 6). The amount of inward movement is regulated by the screw f (Fig. 4) which forms the stop for the inward movement of the wedges. This screw taps into the relief-plate, and against its head the cross-piece of the wedge strikes. When the handle E is turned to the left as far as it will go, the wedges are back against the collars and are in proper working position; when, on the contrary, the handle is moved to the right, the screw which works through the stuffing-box forces the wedges inward and throws off the relief-plate. About one half turn of the handle is all that is necessary. The purpose of this handle and screw is to afford a means of separating the valve-faces from seats in case they tend to adhere together

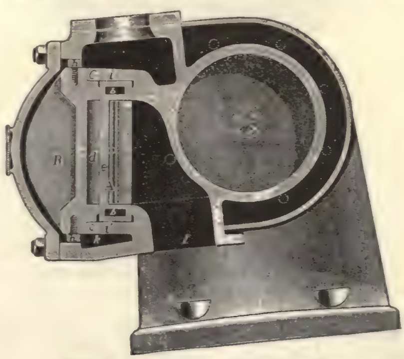


Fig. 2.—Cylinder - vertical section.

after engine has been standing for some time. The valve *A* (Fig. 8) besides taking steam at the ends, has supplemental admission ports *a a′* (Fig. 7) which are connected at top and

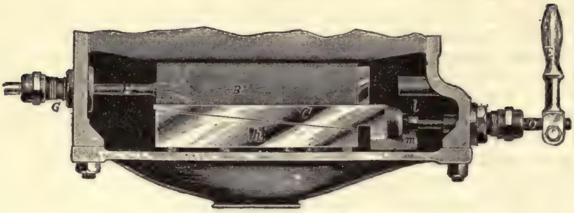


Fig. 3.—Steam-chest—section.

Fig. 5.—Wedge. Fig. 6.—Screw.

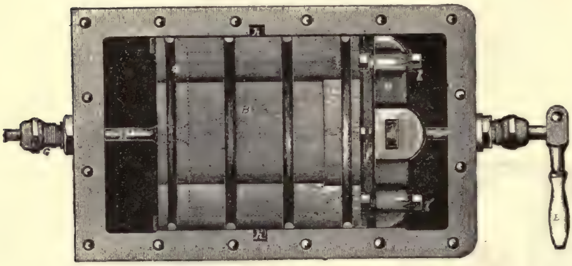


Fig. 4.—Steam-chest—uncovered.

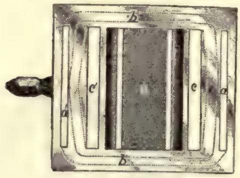


Fig. 7.—Valve.

bottom by passages *b b′*. The steam is entering cylinder-port directly past the end of the valve, and also through the cavity in the relief-plate into port *a′*. Steam is at the same time

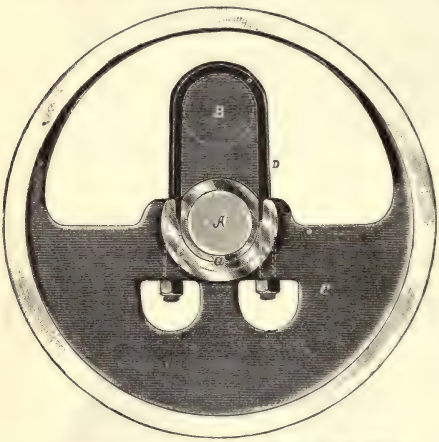
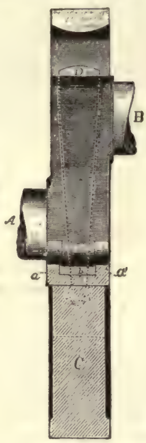


Fig. 8.—Balancing-disk.



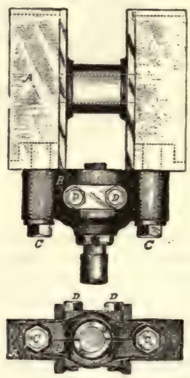


Fig. 9.—Cross-head.

entering supplemental port *a* at opposite end at two points, and traveling through the horizontal passages into port *a′* and cylinder-port. The admission, therefore, takes place at four points at the same time, and, as the ports are very large, the nearest approach to boiler-pressure is reached, and the usual loss between boiler and cylinder reduced. A double exhaust is also used.

Fig. 8 shows the method of attaching the counter-weighted disks to the cranks for the purpose of balancing the reciprocating parts.

Fig. 9 shows the cross-head in top and end view, the piston-rod being in section.

The construction of the main connecting-rod is shown in Fig. 10.

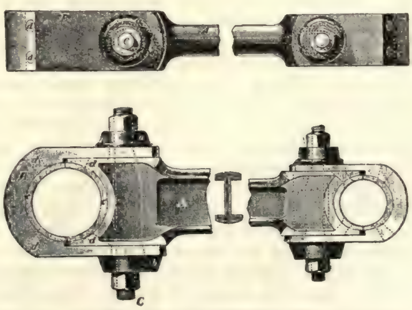


Fig. 10.—Connecting-rod.

Sweet's Straight-Line Engine, built by Sweet's Manufacturing Co., Syracuse, is shown in Figs. 11 to 22. The frame consists of two straight arms running from the cylinder to the main bearings, with the balance-wheels between, the whole resting on three self-adjusting

points of support. All strains go in straight lines; all boundary-lines are straight, ending in curves; all cross-sections of stationary parts are rectangular, with rounded corners; and all moving arms and levers are double convex, wide and thin, with the longest axis in the direction of the greatest strain. The frame is cast in one piece with the cylinder and steam-chests.

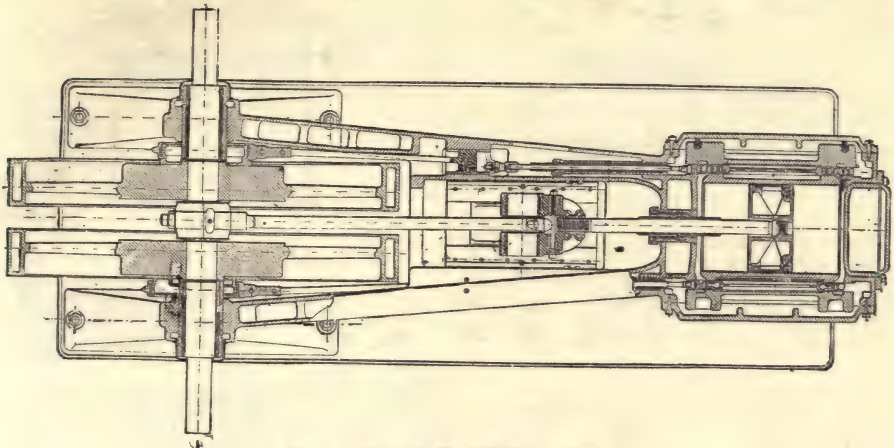


FIG. 11.—Sweet's straight-line engine.

The pistons in engines smaller than 10-in. cylinder are solid, with rings sprung in, but for 10 in. and over they are as shown in Fig. 13. The main characteristic is that the rings are made much too large for the cylinder, sprung in with considerable force and pinned in that position, and the outside turned to a perfect fit to the cylinder. After this, the pin-holes in the rings are filled to admit of the rings being compressed, while not allowed to expand. Only a part of the thickness of the piston is used to secure it to the rod, this being done to give additional length to the piston-rod bush. The castings are very thin and light, and are thoroughly ribbed for strength. The only part that can wear is the bull-ring, which is packed down to keep the piston in the center of the cylinder by liners made of narrow strips of sheet metal. Flanges cast on the spider and follower inside of the piston-rings make them so stiff that only four studs are used. The pistons are secured to the rods by two taper fits, a parallel thread, and shrink fit.

The piston packings are simply Babbitt-metal bushings, with reamed holes slightly larger than the rods, so as to be a free sliding fit. One form is shown in Fig. 14. They rest in spherical seats, which are free to move in any direction.

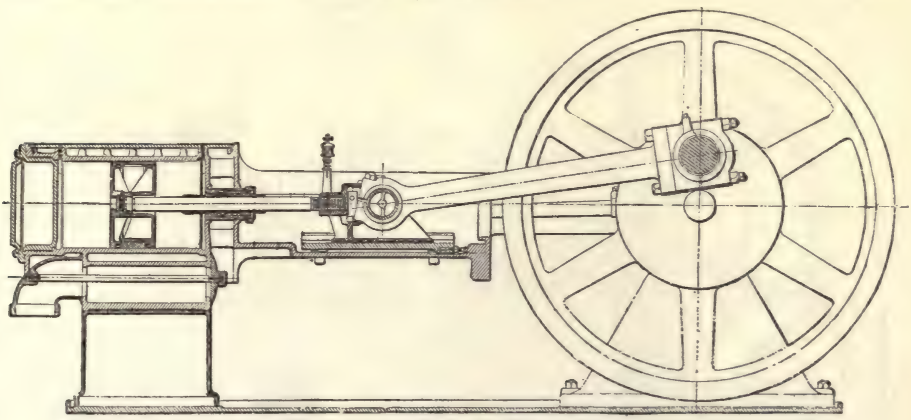


FIG. 12.—Sweet's straight-line engine.

The cross-head is shown in Fig. 15. It is of steel or malleable iron casting, and is threaded on the piston-rod and secured by being split and clamped by the binding-bolts. The cross-head pin is a hollow steel casting made fast to the connecting-rod, and turns in two adjustable Babbitt-lined boxes in the cross-head. The object of this is to secure lightness, extra wearing surface, to prevent side swinging of the connecting-rod at the fly-wheel end, and to give ready means of oiling. The cross-head is what is known as the slipper-guide sort, the lower guide being adjustable in the vertical direction. It rests upon and is bolted upon two inclined planes, and may be readily raised or lowered to bring the piston-rod in perfect alignment.

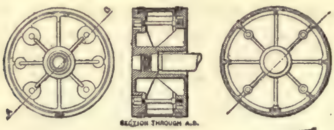


FIG. 13.

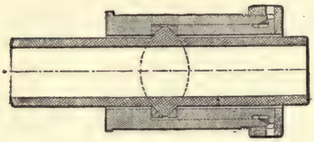


FIG. 14.

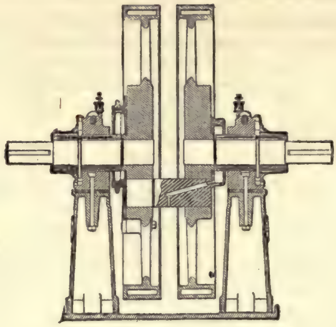


FIG. 16.

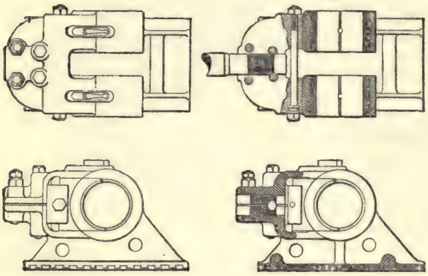


FIG. 15.

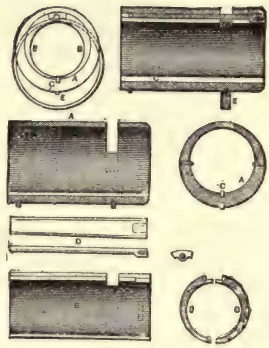


FIG. 17.

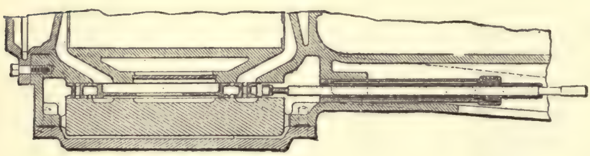


FIG. 21.

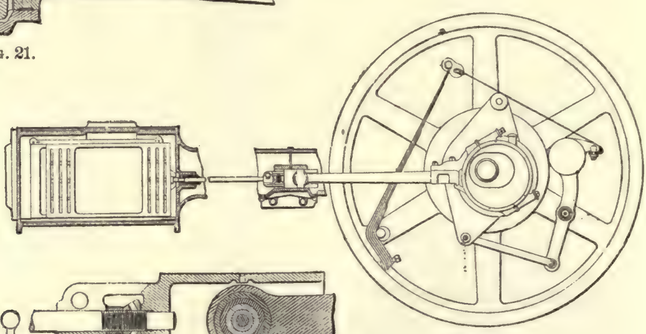


FIG. 18.

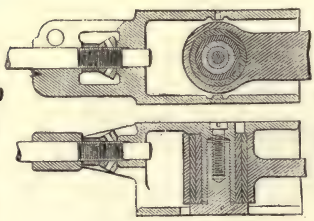


FIG. 19.

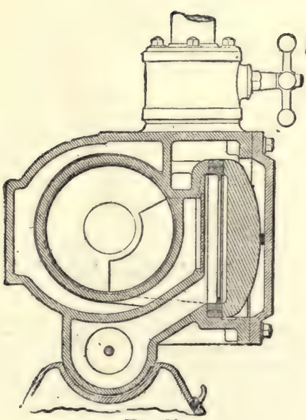


FIG. 20.

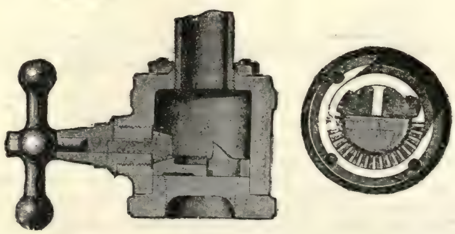


FIG. 22

FIGS. 13–22.—Details of Sweet's straight-line engine.

The crank-shaft and wheels are shown in Fig. 16. The steel crank-pin and shafts forced into the large bosses of the two wheels form a solid structure, dividing the strain equally between the bearings, and give an opportunity to balance the reciprocating parts properly, furnish a support for the governor, and relieve the main bearings of a good part of the thrust of the piston.

The main journal-boxes are shown in Fig. 17. These sleeves, A, are made eccentric and lined with Babbitt-metal cheek-pieces B, which bring the shaft concentric with the outside of the shell. The cheek-pieces are retained in place by Babbitt-metal feather C at the bottom, and a brass wedge D at the top. This furnishes a complete bearing at the bottom and sides, and one in which the wear can be compensated for. Narrow metal liners are introduced at the bottom, which can be removed and placed by the side of the wedge at the top. By this change the cheek-pieces are shifted down, and, being wedge-shaped, the opening is closed.

The governor, shown in Fig. 18, consists of a single ball linked to the eccentric and connected to a spring by a metal strap, and so located and weighted as to counterbalance the eccentric and its attachments. When the speed of the engine reaches the point where the centrifugal force of the governor-ball overcomes the resistance of the spring, the ball moves away from the center of rotation, and in doing so it carries the eccentric nearer the shaft, shortens its throw and the travel of the valve, and reduces the steam admitted to the cylinder.

The eccentric is cast upon a swinging plate, which is pivoted to the boss of the fly-wheel. The eccentric-plate is subject to a twisting strain, to resist which, in addition to the long stud and journal, there are two links connecting it to the governor-ball.

The valve motion has two peculiarities: the position in which the eccentric-plate is pivoted to the wheel, which gives a variable lead to the steam admission, and the direct connection between eccentric and valve. The method of securing the slide to the valve-rod is shown in Fig. 19. The method of securing the rod to the valve admits of the valve being removed and returned without disturbing the adjustment.

The valve controls the distribution of steam very much as is done by the common D valve, but having a variable travel controlled by the governor, it varies the amount of steam admitted as the work imposed on the engine varies. The valve, as will be seen in Fig. 21, is a rectangular plate, quite thin, and with five openings through it. It is made flat on its two sides, and of uniform thickness. The valve works within an opening formed by the valve-seat and a pressure-plate and two distance-pieces placed above and below it (see Fig. 20). The pressure-plate has recesses in it opposite the ports in the valve-seat, and the distance-pieces are made about $\frac{3}{1000}$ in. thicker than the valve. The pressure-plate resting against the distance-pieces relieves the valve of all pressure, and it works within its opening the same as a piston-valve. By the recesses in the pressure-plate and the small openings through the valve double ports are opened both for steam admission and exhaust.

The throttle-valve, shown in Fig. 22, consists of a flat seat, circular in form, having a semicircular opening through it, and a valve whose face is a counterpart of the valve-seat, and by means of a semicircular bevel-gear on its upper surface and a pinion it can be rotated half-way around. When the valve is set in such a position that the two openings coincide, there is a straightway passage for the steam, and when turned in the reverse way the valve is closed.

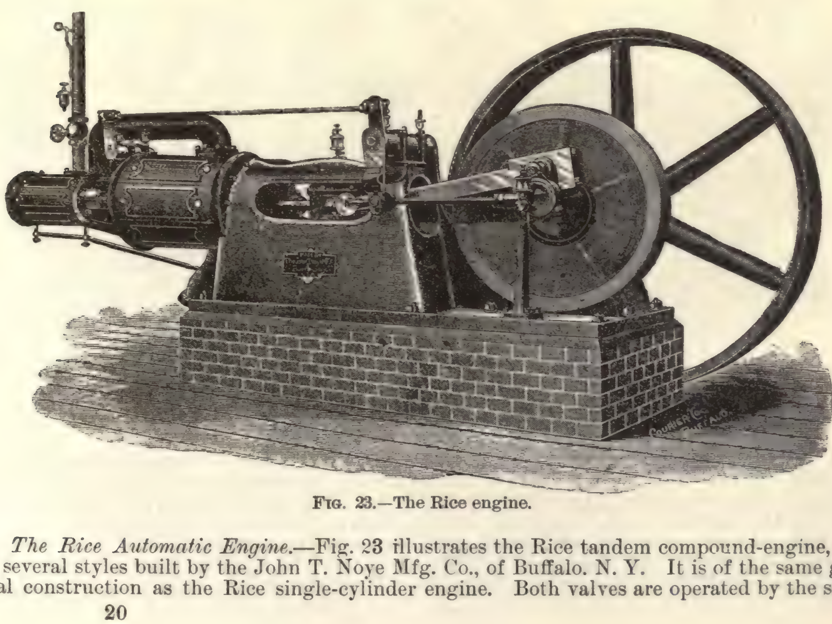


Fig. 23.—The Rice engine.

The Rice Automatic Engine.—Fig. 23 illustrates the Rice tandem compound-engine, one of several styles built by the John T. Noye Mfg. Co., of Buffalo. N. Y. It is of the same general construction as the Rice single-cylinder engine. Both valves are operated by the same

governor through the same eccentric-rod. The valves can be set independently of each other, the low-pressure valve being arranged to admit of considerably more travel than the high-pressure.

The valve of the Rice engine is shown in Fig. 24. It is balanced from all pressure higher than the exhaust, the steam being admitted from the inside and allowed to nearly

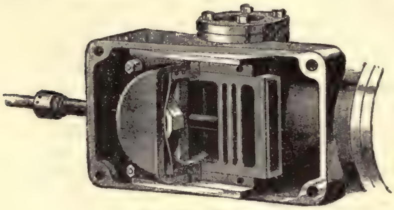


FIG. 24.—Valve.

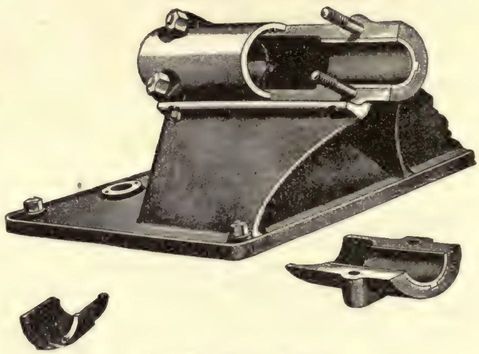


FIG. 26.—Main bearing.

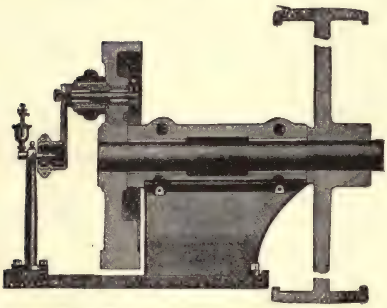


FIG. 25.—Main bearing—section.

surround the entire valve. The valve can be easily operated with one hand upon the smooth valve-stem, when under full pressure of steam. The relief-valve is in the form of a steam-tight piston, which rests on shoulders even with the valve (not on the valve itself), and is

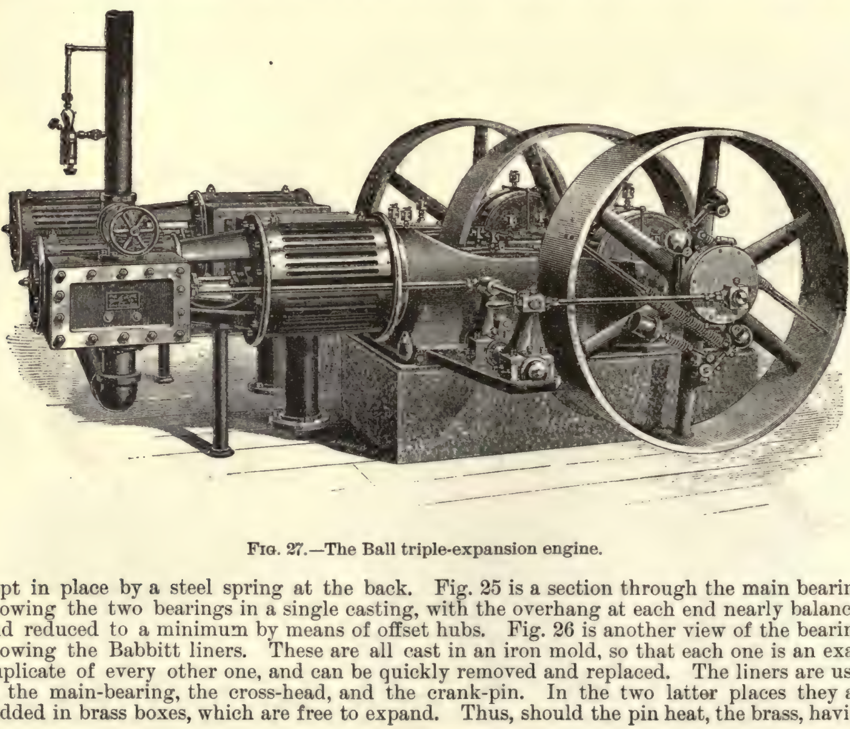


FIG. 27.—The Ball triple-expansion engine.

kept in place by a steel spring at the back. Fig. 25 is a section through the main bearing, showing the two bearings in a single casting, with the overhang at each end nearly balanced and reduced to a minimum by means of offset hubs. Fig. 26 is another view of the bearing, showing the Babbitt liners. These are all cast in an iron mold, so that each one is an exact duplicate of every other one, and can be quickly removed and replaced. The liners are used in the main-bearing, the cross-head, and the crank-pin. In the two latter places they are bedded in brass boxes, which are free to expand. Thus, should the pin heat, the brass, having

a greater expansive power than steel or iron, and being free, will expand and loosen the fit, instead of tightening it, as is the case when bound with an iron band.

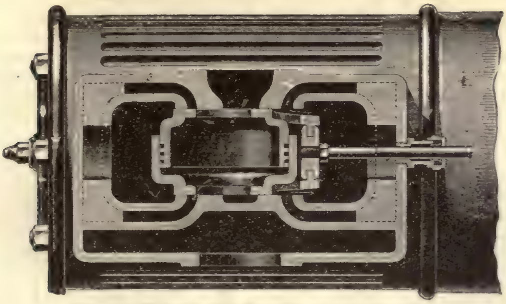


FIG. 28.—Ball engine steam-chest.

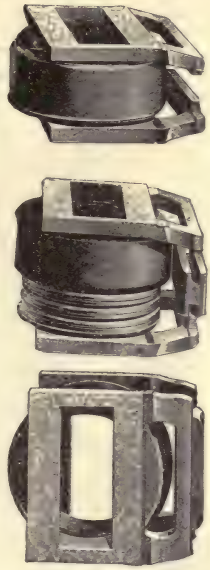


FIG. 29.—Valve.

The Ball Engine.—Fig. 27 represents a double-tandem condensing triple-expansion engine made by the Ball Engine Co., Erie, Pa. This engine is built in sizes of 300, 400, 500, 600, and 700 horse-power.

Fig. 28 shows a section through the steam-chest and valve of the Ball engine. Fig. 29 shows three views of the construction of the valve. It consists of two parts, which are connected by telescopic sleeves, allowing each half to adjust itself to its seat. The sectional view shows the manner of steam distribution to the cylinder, and the operation of the valve. This double-faced valve is held in constant and steam-tight contact with an upper and lower horizontal valve-face, whose areas, in proportion to the surface of the valve, are identical. The live steam enters the upper side of the valve, and, being inclosed by the telescopic shells, presses the faces apart with relation to each other, and against the port or passage-way surface, as shown. By this arrangement there is only a sufficient percentage of the whole area of each valve subjected to unbalanced pressure to insure steam-tightness.

The Ball & Wood Cross-Compound Engine.—Fig. 30 shows a perspective view of a cross-compound engine built by the Ball & Wood Co., of Elizabeth, N. J., for the Newark Electric

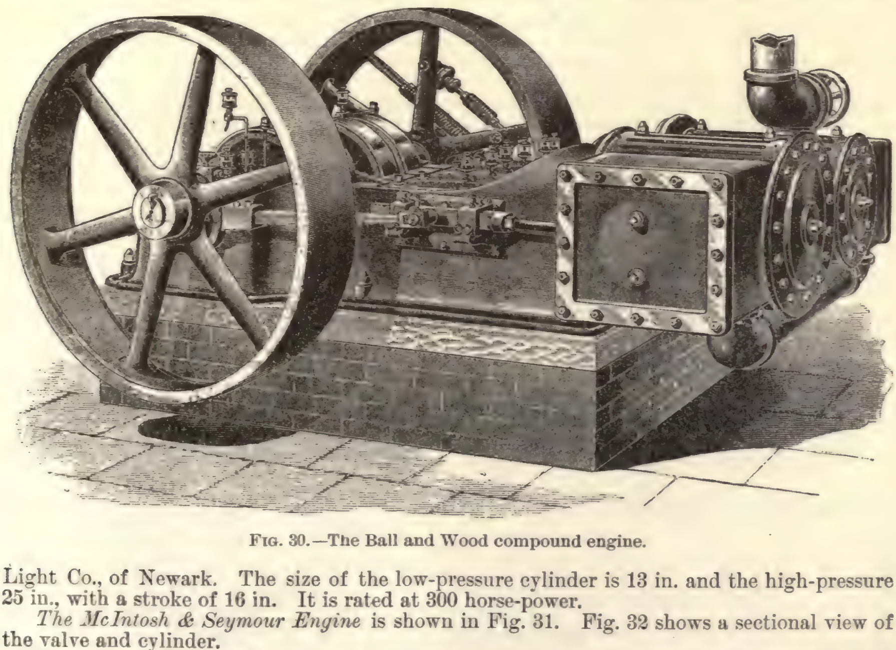


FIG. 30.—The Ball and Wood compound engine.

Light Co., of Newark. The size of the low-pressure cylinder is 13 in. and the high-pressure 25 in., with a stroke of 16 in. It is rated at 300 horse-power.

The McIntosh & Seymour Engine is shown in Fig. 31. Fig. 32 shows a sectional view of the valve and cylinder.

The general design of the engine presents no radically novel features except in two vital points, the valve and governor. The frame is made very massive and rigid by heavy internal ribbing. The lower guides are separate pieces, though supported throughout their entire

length by the frame. The main bearings have cheek-pieces for taking up horizontal wear. Each one of these is backed up solidly for its entire length by a taper-wedge, and can be adjusted by elevating the wedge with screws provided for that purpose. The main caps can be removed entirely without disturbing the cheek-pieces or wedges, and the latter can then be removed without disturbing the shaft, exposing over one half of the circumference of the journal. The cross-head is of the locomotive type and is made of one piece, including cross-head pin. The construction of the valve and valve-seat is shown in the sectional views through cylinder and steam-chest, in Fig. 32. The valve proper is an ordinary piston-valve.

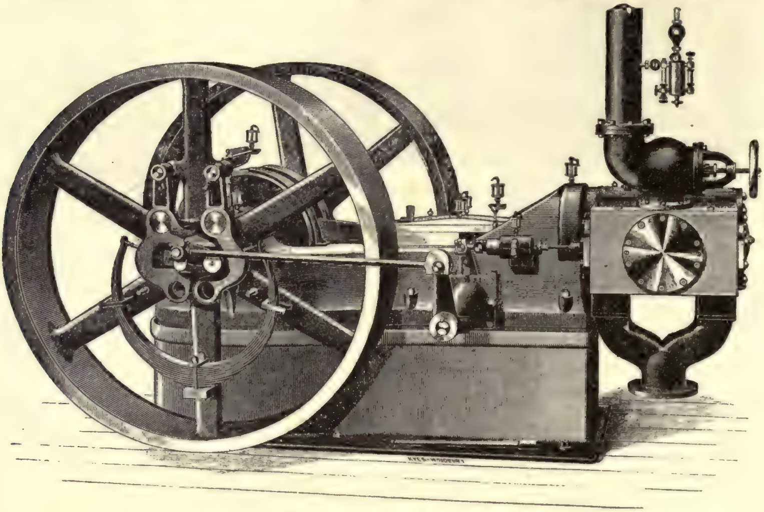


Fig. 31.—The McIntosh and Seymour engine.

The valve-seat is so constructed that it can be taken up to compensate for its own wear and that of the valve. This seat consists of a ring, or rather two rings, made in one piece and connected by several bridges across the port-opening which the space between them forms. The seat is crescent-shaped, split and adjustable to fit the valve, by the stem which extends to the upper side of the steam-chest, where it can be turned by a box-wrench, as shown in the cut, after removing the cap which covers its end. By disconnecting the eccentric-rod from the valve-rod slide or rocker and moving the valve to and fro by hand while turning the stems, a very close adjustment of the seats to the valve can be made without any danger of making them too tight for the valve to work freely. Each adjustable seat is held steam-tight between two permament seats, but is free to move in the plane of the port and may be said to ride on the valve. This arrangement makes the valve less liable to stick than with a rigid seat, if the engine is started without warming it up thoroughly. The steam does not enter the port-openings from the steam-chest over the inside edge of each valve-end, as is usually the case, but through port-shaped openings in the rim of the valve, leaving a detached portion on the inner edge of each valve-rim, which greatly increases the bearing-surface of the valve. This engine has proved exceedingly efficient as a motor for dynamos.

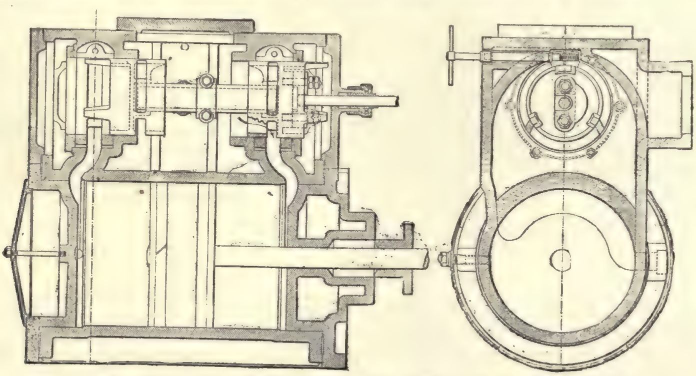


Fig. 32.—McIntosh and Seymour engine section—valve and cylinder.

The Giddings Compound Automatic Engine is shown in Fig. 33. It is built by the Sioux City Engine Works, Sioux City, Iowa. The special feature of this engine is a novel device

for packing the piston-rod between the two cylinders. The space between the cylinders is jacketed and provided with a means for opening, to test for leakage around the piston-rod and

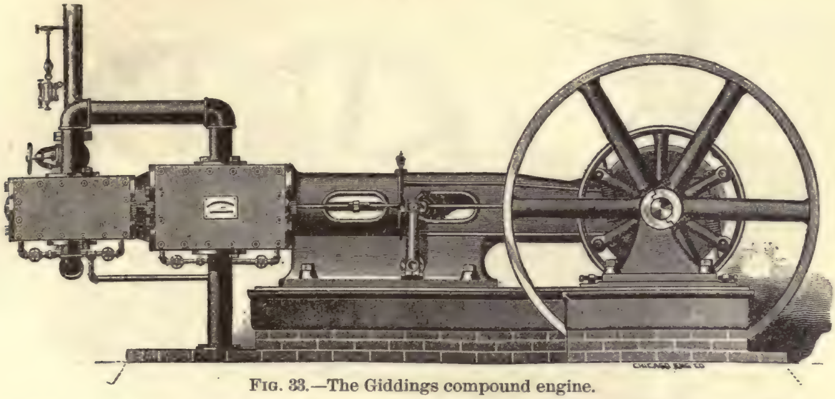


Fig. 33.—The Giddings compound engine.

to adjust or renew the packing. The intermediate receiver has been discarded in these engines.

The Giddings Valve.—Fig. 34 shows the Giddings equilibrium slide-valve, used in the Giddings high-speed automatic engines. This slide-valve consists of one piece; takes steam from underneath, supplies the cylinder through double ports, giving twice the original port area, and close approximation to boiler-pressure. It is self-adjusting to wear and position, and is free to lift from its seat a sufficient amount to relieve the cylinder from water. Equilibrium is obtained by two needle ports in brass plugs in the top edge of the valve, one supplying live steam to the back of the valve to avoid lifting, another connecting with the exhaust-passage, thereby preventing accumulation of pressure, and still maintaining about 2 lbs. of surplus pressure per sq. in. on the back of the valve, which insures a positive and permanent tight joint. The connection is made by a hinge-joint, whereby the valve can be opened outward like a door, without disconnecting.

Fig. 34.—The Giddings valve.

The Valley Engine.—Fig. 35 shows the balanced valve used by the Valley Iron Works, Williamsport, Pa., on their automatic high-speed engine. It consists of but one piece, and has no rings or sleeves. The shape is clearly shown in the illustration. It is set in the valve-seat, with the corner pointing to the center. Between the cover and cover-seat are placed strips of copper $\frac{1}{100}$ in. in thickness, which are for the purpose of removal and taking up wear as the valve may require it. The objection to wear existing in the piston-valve is overcome by this construction. Live steam is admitted inside the cover around the valve, and exhaust let out at the ends. This construction admits of the engine being run under full boiler-pressure with the exhaust-cover removed, and an inspection of valve for leakage made under full steam-pressure. The construction of the valve-bracket and slide is shown in Fig. 36. The bracket is bolted to the bed and carries the slide, between the bracket and stuffing-box. On the valve-stem is a clamp-wrist, split in the back and pinched on the slide by a $\frac{1}{2}$-in. bolt, as shown. In case of accident or of the valve striking the end of chest, this wrist will slip, preventing all damage. Fig. 37 is a perspective view of the engine.

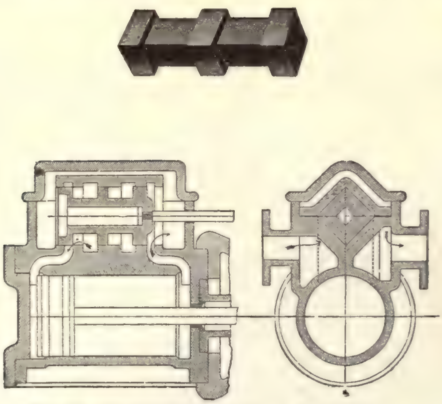


Fig. 35.—Valley engine valve and cylinder.

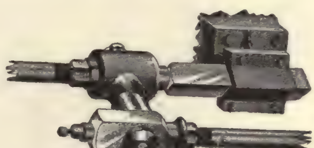


Fig. 36.—Valve-bracket and slide.

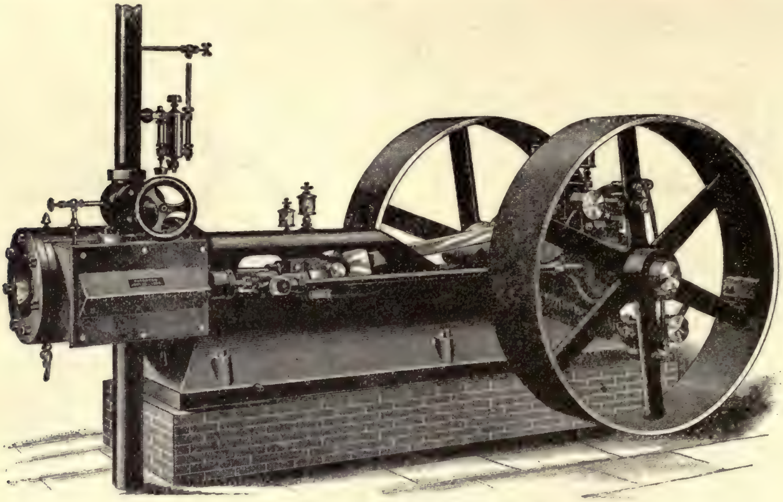


FIG. 37.—The Valley engine.

The Armington & Sims Engine.—Two recent styles of the Armington & Sims engine are shown in Figs. 38 and 39. The first is a double compound engine, with cranks at 180°, and

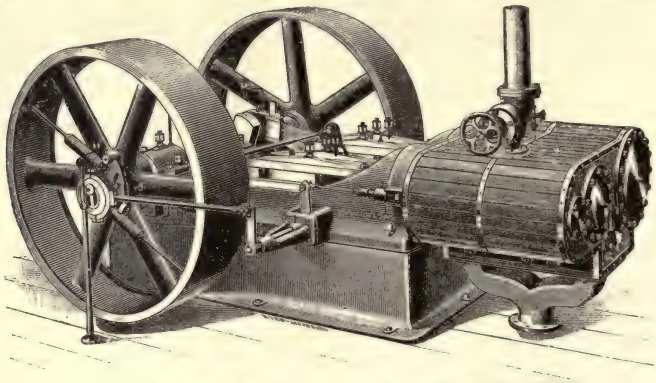


FIG. 38 —The Armington and Sims engine.

the second is known as a special double engine, especially designed for electric-lighting on board of steamships, where saving of space is a prime requirement. Numerous other forms

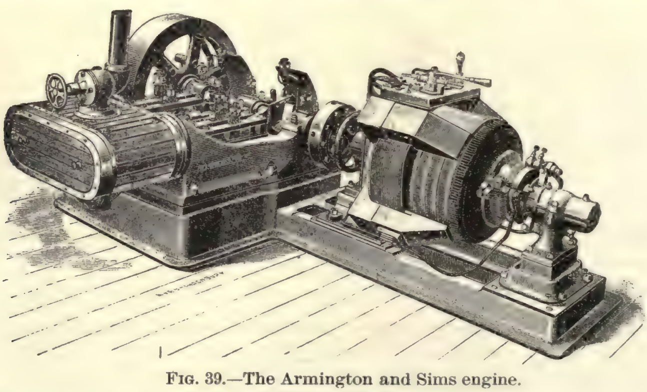


FIG. 39.—The Armington and Sims engine.

of engine are built by the Armington & Sims Co., of Providence, R. I., such as vertical double-acting compound engines, etc., all of which are developments from the original engine built

by this company with a single cylinder. A section of the cylinder and valve of the Armington & Sims engine is shown in Fig. 40. The steam-chest, with valve-seat, is in one casting with the cylinder; the valve-chest is inclosed by a cover in the usual manner. It will be seen that the steam-chest is filled with live steam, which surrounds the valve, and that by taking steam in the center of the valve and exhausting at each end, the steam-ports from the cylinder can be very direct, and the waste-room kept small. In the engraving the valve is shown as just taking steam into the cylinder-port at the piston-end; the port in the valve at the other end is also just taking steam from the steam-chest into a port which passes through the valve into the same cylinder-port; this enables steam to be taken very quickly at the commencement of the stroke. The steam is exhausted at each end of the valve by direct passages which quickly free the cylinder. The piston is hollow, fastened by a taper fit to the rod, and furnished with two snap-rings. The valve is a hollow piston-valve, with cast-iron ends, made very light, with a body of steel tubing. It is ground, and perfectly balanced.

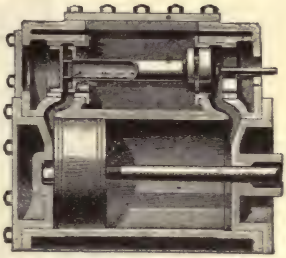


Fig. 40.—Valve and cylinder.

The Harrisburg Tandem-Compound Engine.—The Ide tandem-compound engine, as manufactured by the Foundry and Machine Department, at Harrisburg, Pa., is shown in Fig. 41.

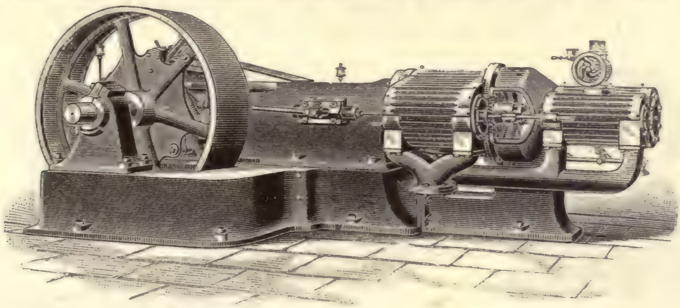


Fig. 41.—The Harrisburg compound engine.

The extra heavy shaft and fly-wheel are supported between the bearings, avoiding the overhang of the fly-wheel, as is the case in the center-crank type. One of the special features in the Harrisburg tandem compound is the method of connecting the high and low pressure cylinders. It admits of moving the low-pressure cylinder head into the connections to examine the low-pressure cylinder and piston without removing the high-pressure cylinder or its steam and exhaust connections. The inability to do this has been one of the greatest objections to the tandem-compound engines as usually built. The manner of supporting the high-pressure cylinder is more substantial than the general practice, avoiding the vibration of cylinders when working under full load.

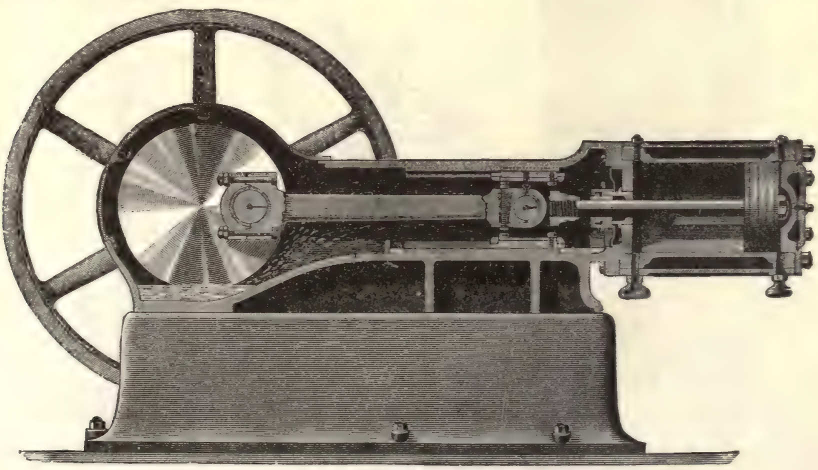


Fig. 42.—The ideal engine.

The Ideal Engine, made also by the same builders, is shown in Figs. 42 and 43. It is a single-cylinder automatic engine, with the peculiar feature of being self-lubricating. The sectional view shows the principle of the automatic oiling device.

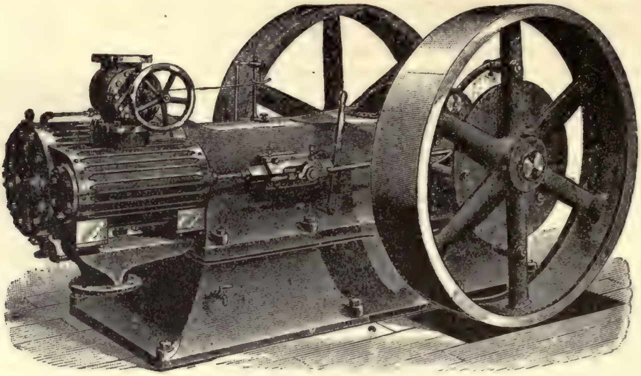


FIG. 43.—The ideal engine.

The Sioux City Corliss Engine, of the tandem compound class, is shown in perspective in Fig. 44. Fig. 45 is a half-section of the cylinder, showing that the steam is taken between

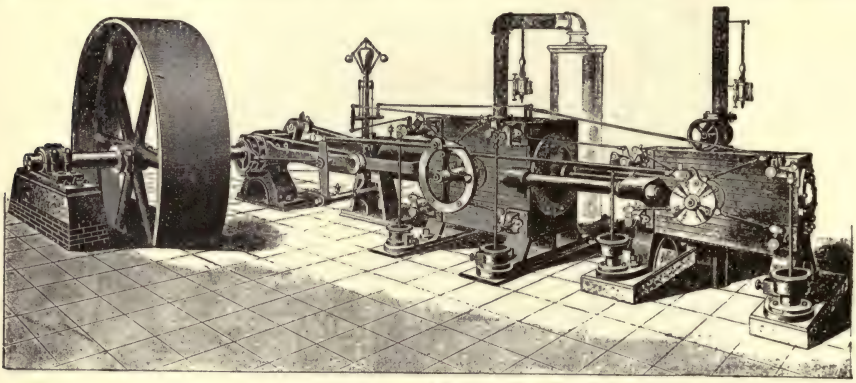


FIG. 44.—The Sioux City Corliss engine.

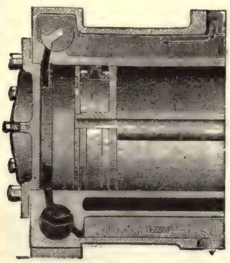


FIG. 45.—Cylinder.

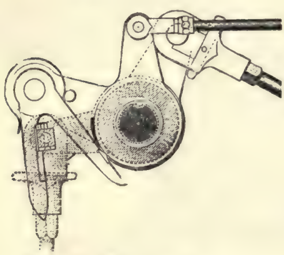


FIG. 46.—Valve-gear.

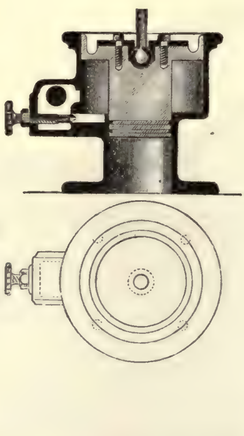


FIG. 47.—Dash.

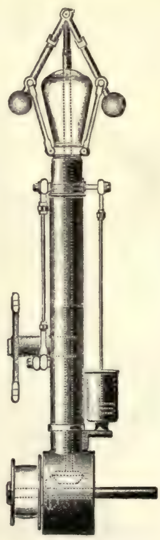


FIG. 48.—Governor.

FIGS. 45–48.—Sioux City Corliss engine—details.

(not over) the valves, and that the exhaust-chamber is cast separate and independent from the cylinder, thereby preventing a cold, wet steam-jacket. The steam-valves are all made so as to

relieve themselves in case of water. Fig. 46 shows the hook-motion valve-gear, Fig. 47 the dash, and Fig. 48 the governor, which has light balls made to run at three times the speed of the engine, and a heavy sliding weight.

The Fishkill-Corliss Engine.—A sectional view of the cylinder of this engine is shown in Fig. 49, and a side view of the valve-motion is shown in Fig. 50. Cité's releasing valve-gear, as applied to this engine, is shown in the accompanying detailed cuts.

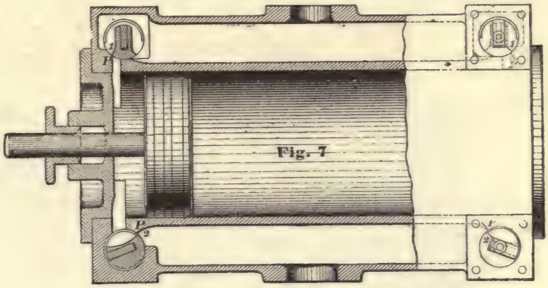


Fig. 49.—Fishkill-Corliss engine—cylinder.

Fig. 51 is a front elevation, and Fig. 52 is a plan. These show the valve-gear as it appears when engaged, and in the middle of its travel. Figs. 53, 54, and 55 are rear elevations. Fig. 53 shows the parts in engagement at the moment the valve begins to open; Fig. 54 shows the position of the parts immediately after the valve has been released, and Fig. 55 illustrates the action of the stop-motion.

In all the figures *A* represents the valve-stem and *B* the valve-lever, which is secured to the end of the valve-stem by a feather and set-screw. *C C′* is a double crank, which vibrates loosely on a sleeve around the valve-stem, and is connected by an adjustable link-rod to the wrist-plate, from which it receives its motion. The end of the arm *C* carries a small rock-shaft *D*, which has a hook *E* fastened on one end. This hook is provided with a hardened steel catch-plate *b*, which engages a similar plate *c* fastened on the end of the valve-lever *B*, and the hook is kept in place by a light spring *f*. On the end of the rock-shaft *D*, opposite the hook *E*, is fixed a forked crank *F* having a pin *h* on which is mounted a sliding-block *s*, and the outside of block *s* is fitted to move in a slot *i* of a link *G*. The link is mounted at and vibrates about a point *j* in one arm of a bell-crank *H*, and the bell-crank oscillates upon a sleeve around the valve-stem. The other arm of the bell-crank *H* is connected by an adjustable rod *z* to the governor. By referring to Fig. 53, in which the double crank *C C′* is moved by the wrist-plate in the direction indicated by the arrow, and following the motion of the inner end of the block *s*, and also of the inner end of the slot *i*, it will be seen that these points will come together when the curved dotted lines 2 and 3 cross each other, and as the movement continues the block *s* will be pushed farther from the center of the valve-stem, and when the center line of the link shall be coincident with radial line 1, as shown in Fig. 54, the block will have been pushed so far outward that it will have slightly turned the small rock-shaft *D*, and moved the hook *E* enough to release the valve-lever *B*. Then the dash-pot will act and close the valve. At this moment of release, effected by the toggle-like action of the link, the pressure on the bell-crank *H*, caused by the liberation, will be exerted in a radial line from the center of the slot through the point *j* to the center of the valve-stem or the stand which supports it, and during the entire movement of the hook *E* there will be no appreciable strain to turn the bell-crank *H*, and consequently there will be no strain to disturb the normal action of the governor. As the position of the bell-crank *H* is controlled by the governor, any change in the height of the governor will cause a change in the position of the point *j*, and a corresponding change in the time of release. The action of the automatic safety-stop motion is illustrated by Figs. 53 and 55. Fig. 53 shows the position of the various parts when the engine is at its lowest normal speed, and the hook *E* is at the point of engagement with the valve-lever *B*. The lower side of the link *G* is provided with an adjustable embossment *w*, which, in the position shown, is just clear from the hub of the bell-crank *H*. Now, should the governor-

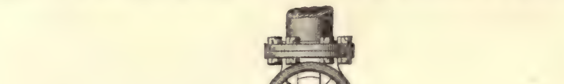


Fig. 50.—Fishkill-Corliss engine—valve-motion.

belt be broken, or if from any other cause the governor-balls should fall below this point, the bell-crank H will be moved in the direction indicated by the arrow in Fig. 55, the emboss-

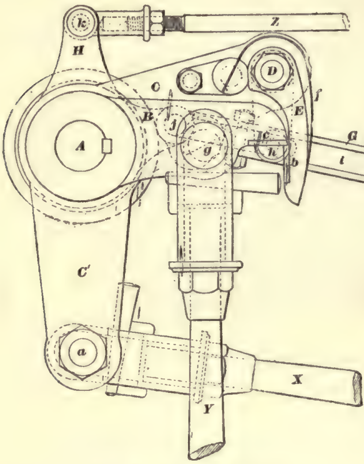


FIG. 51.—Front elevation.

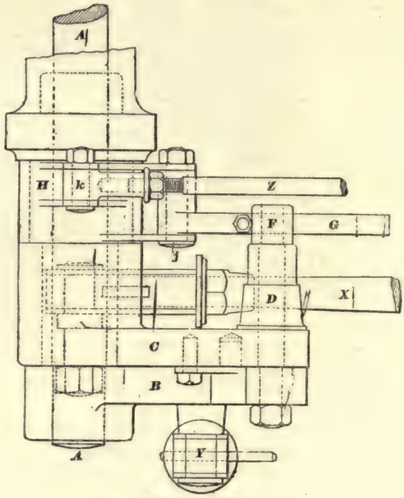


FIG. 52.—Plan.

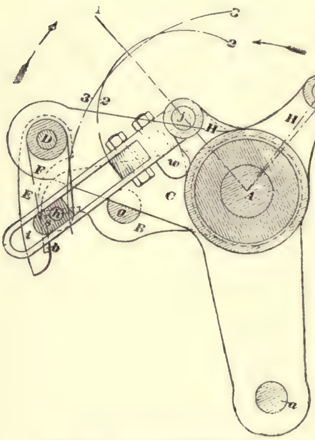


FIG. 53.—Valve begins to open.

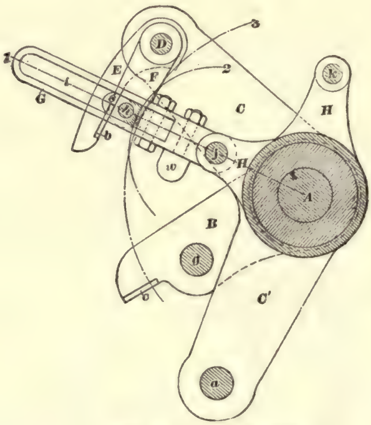


FIG. 54.—Valve released.

ment w will be brought against the hub of the bell-crank, and the continued movement of the bell-crank will cause the embossment to act as a fulcrum, and the lower side of the slot i will cause the pin h in the forked crank F to move outward, or from the center of valve-stem A. This will carry the hook E outward so far that it will not engage with the valve-lever B, and the valve will remain closed. In connection with the above, an attachment is placed on the governor-column, by means of which the action of the stop-motion may be suspended or made operative at any time by the engineer, and when suspended the engine can be stopped and started in the usual way.

The Payne-Corliss Engine.—In the engine illustrated in Fig. 56 separate valves have been provided for the induction and exhaust; the steam-chest and induction-valves situated above, and the exhaust-chest and valves below, as in the conventional Corliss engine. There are, however, separate wrist-plates for the steam and exhaust valves. The wrist-plate, which gives motion to the exhaust-valves, derives its movement from a fixed eccentric upon the main shaft, and thus the points of release and compression may be adjusted without interfer-

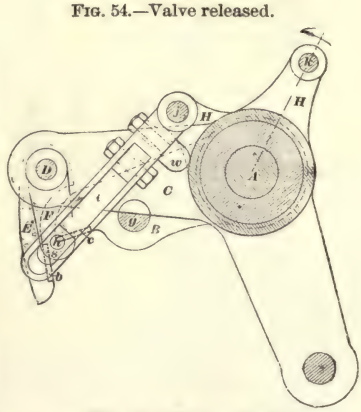


FIG. 55.—Stop-motion.
FIGS. 51–55.—Cité's releasing valve-gear.

ing with the functions of the steam-valve, and, once determined, are positive and fixed. The eccentric, which determines the movement of the steam-valves, is operated by a shaft-governor in such a manner as to open the valves more or less according to the amount of steam required, varying the point of cut-off, while the amount of lead remains practically constant for all loads and pressures. The point of cut-off being varied by the greater or less movement of the wrist-plate instead of by means of a detachable motion, and the valves being closed by a

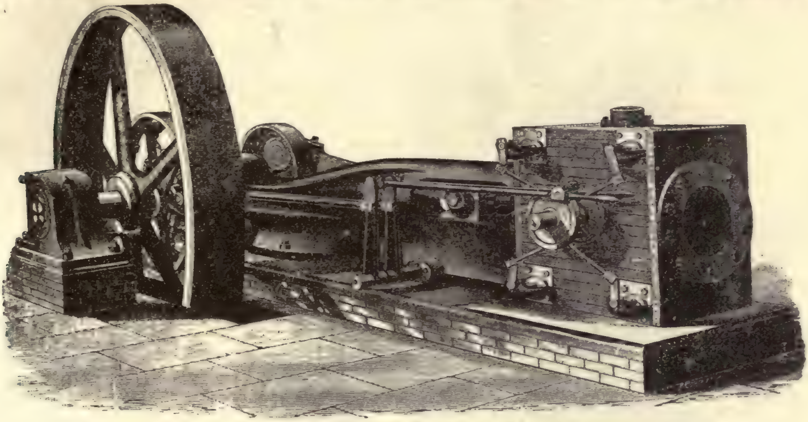


Fig. 56.—The Payne-Corliss engine.

positive connection with the wrist-plate instead of by dash-pots, high rates of rotation and the advantages of the high-speed engine, combined with a distribution of steam to which the economy of the 4-valve engine is due, are rendered possible, inasmuch as the engine is not limited by the inability of the detachable devices to act at high rotative speeds.

The Westinghouse Engine.—The Westinghouse engine is the leading engine of a new type which has recently come into extensive use, the principal characteristics of which are (1) two or more vertical single-acting cylinders, and (2) automatic lubrication by means of a closed chamber surrounding the crank-shaft, containing oil or oil and water. This type of engines was originally built with two cylinders of the same size, with cranks at 180°. Large sizes are built as a compound engine, with one cylinder larger than the other. Engines on the same general principle, but with three cylinders and triple expansion, with three cranks at 120°, have been brought out by other makers. Among the advantages claimed for this type of engine are, that, on account of its being single-acting, the pressure of the piston and of the connecting-rods on the wrist and crank pins is always in one direction, viz., downward, and consequently, no matter how much the bearings are worn, there is no lost motion in them. On this account, the engine, if properly designed, may be rnn at a very high speed, and is therefore economical of room and weight, and saves the gearing for transmission of power to the line-shafting machine or dynamo, necessary with slow-speed engines.

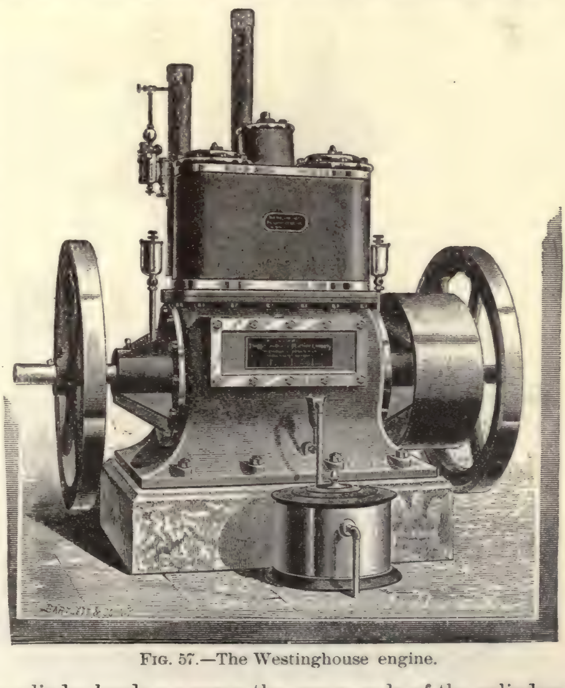


Fig. 57.—The Westinghouse engine.

Fig. 57 shows a front view, and Figs. 58 and 59 sectional views, of the Westinghouse "standard" or non-compound engine as built in sizes from 15 to 250 horse-power. The following is a description of the details: The cylinders A A are cast in one piece with the valve-chamber B, and are bolted to the top of the bed or crank-case C. The cylinder-heads a a cover the upper ends of the cylinders only, the lower ends being uncovered and opening directly into the chamber of the crank-

case. The pistons $D\ D$ are of the "trunk" form, double-walled at the top to prevent condensation, open at the bottom, and carrying the hardened steel wrist-pins $b\ b$. They are each packed with three rings. The connecting-rods $F\ F$ are made of forged steel. The cranks $G\ G$, the crank-pins, and crank-shaft $H\ H$ are all of steel, and may be removed by taking off the crank-case head c. The crank-shaft bearings are in the form of removable shells $d\ d$, lined

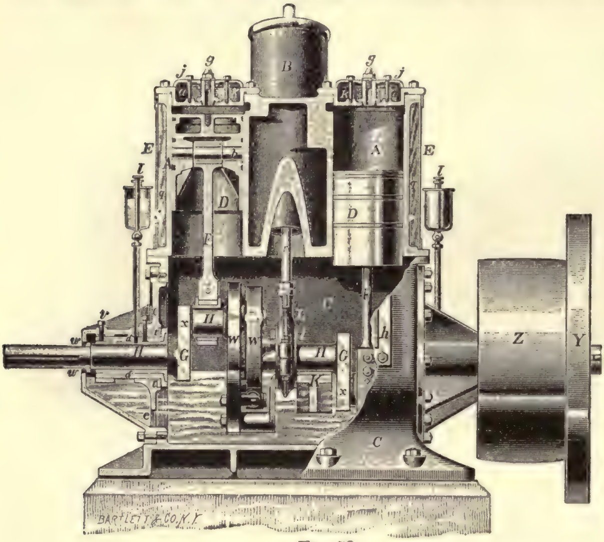


FIG. 58.

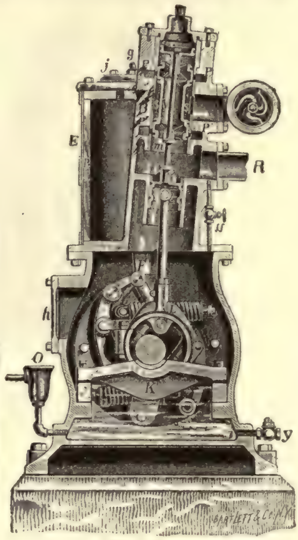


FIG. 59.

FIGS. 58, 59.—Westinghouse engine—sectional views.

with Babbitt-metal. From 60 horse-power up these bearings are split for the sake of convenient removal without taking out the shaft. They are slipped into the crank-case head from the inside, and adjusted by a distance-ring t, which is of an arbitrary thickness dependent on the shrinkage of the casting of the crank-case. A chamber is formed in the outer end of the crank-case head, in which, and revolving with the shaft, is the ring-wiper w, which takes up the oil as it works past the bearings, and returns it through the hollow rib e into the crank-case C. Oil is fed to the engine from the sight-feed cups $l\ l$ on the main bearings; this renders all other lubrication unnecessary, and keeps the engine clean. A siphon overflow, with a funnel-head O, prevents any accumulation of water from rising above the level of the bottom of the shaft, and thus prevents the escape of oil. This overflow may be piped off at the hole in the funnel-head to an oil-separator, shown in Fig. 59, from which it can be skimmed and restored to the crank-case. An adjustable center-bearing K bridges the crank-case, and receives the thrust of the pistons. The bonnet h is removed, to give access to the cranks. The valve V is a piston-valve, packed with two rings in each head. The valve-seat is a removable bushing, in which the ports are cut to an exact register, and which is then forced into its shoulders. Each valve is provided with a back-pressure piston, which

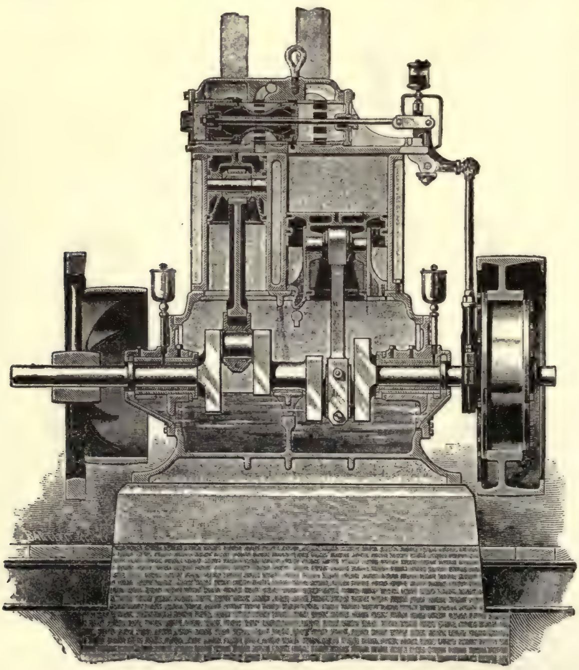


FIG. 60.—Westinghouse compound engine.

prevents the balance of the governor from being disturbed when the engine exhausts against back-pressure. The valve-guide J serves also in lieu of a stuffing-box against the exhaust steam contained in the passage above it. The valve-guide as well as the valve and both pistons are packed with simple sprung rings of cast iron. The valve-stem m is keyed fast to the guide, and grips the valve without binding between the nut at the upper end and the collar at the lower end, as shown. The band-wheel is a combination-pulley Z and fly-wheel Y, cast together, so that the pulley overhangs the main bearing, throwing the line of belt-strain well toward the center of the bearing, and taking the spring off from the shaft.

The automatic governor is located on the shaft, between the cranks, and actuates the valve direct without rock-shafts or other mechanism.

The Westinghouse Compound Engine is similar in general characteristics to the non-compound engine above described. It is shown in section in Fig. 60. One cylinder is enlarged to practically three times the area of the other. The valve-chest is across the top of the cylinders, and is in one piece, the various steam-passages being chambered in it. The valve-seat is in the form of a bush, in which the ports are cut to an exact register. This bushing is reamed out and forced steam-tight into its bored seat.

FIG. 61.—Westinghouse shaft-governor.

The valve-chest also contains a small by-pass valve controlling a cored passage, by which live steam can be admitted to the low-pressure cylinder, to turn the engine over its center when starting. The steam and exhaust connections, are on the side of the valve-chest toward the back of the engine. The valve is actuated by a single eccentric controlled by a shaft-governor, shown in Fig. 61. It is inclosed in a case which is filled with oil when the engine is first set up, and requires no further attention for an indefinite period. The eccentric alone is outside of the governor-case, being carried on a shaft running through a sleeve, and bearing against stops when at full throw.

The economy of steam of the Westinghouse engines is shown in the following figures published by the builders. The first table gives the results of three tests of a non-compound 45 horse-power engine, under three conditions of loading:

Average boiler-pressure....lbs.	91·7	92·5	92·1
" mean effective pressure.... "	39·49	30·76	22·33
" revolutions per min....	352·2	353·9	356·7
" indicated horse-power....h.-p.	44·81	35·08	25·66
Feed-water consumed per indicated horse-power per hour....lbs.	32·60	32·99	36·27

The next table shows the results of tests made in 1888 of a compound engine 14 and 24 in. cylinder, 14-in. stroke, under varying loads. The engine was unjacketed. The steam was measured after being condensed in a surface-condenser, which was less open to the atmosphere in the non-condensing tests. The steam consumption is given in pounds per indicated horse-power per hour:

NON-CONDENSING, BOILER-PRESSURES.				HORSE-POWERS.	CONDENSING, BOILER-PRESSURES.			
60 lbs.	80 lbs.	100 lbs.	120 lbs.		120 lbs.	100 lbs.	80 lbs.	60 lbs.
Steam consumption.					Steam consumption.			
....	....	....	22·6	210	18·4	....	....	....
....	....	23	21·9	170	18·1	18·8	....	....
....	24·9	23·6	22·2	140	18·2	18·5	20	....
....	25·7	23·9	22·2	115	18·2	18·6	19·6	20·5
26·9	25·2	24·9	22·4	100	18·3	18·6	19·7	20·3
27·7	25·2	25·1	24·6	80	18·3	18·6	19·9	20·1
30·3	28·7	29·4	28·8	50	20·4	20·8	20·7	20·4

The Willans Central-Valve Triple-Expansion Engine, made by Willans & Robinson, Thames-Ditton, England, is shown in section in Fig. 62. The piston-valve is shown at the left of the engine.

The engine is arranged with the high-pressure cylinder above the intermediate cylinder, and with the latter above the low-pressure. In engines which have more than one crank, each crank is surmounted by a complete engine, all the pistons of which are carried by one piston-rod. The rod is of large diameter and is hollow, and the valve for admitting and exhausting the steam from the several cylinders works up and down inside it, in the center of the engine (hence the name "central-valve"). It is driven in the usual way by an eccentric, but since the valve-face (i. e., the inner surface of the hollow rod) moves up and down with the pistons, the source of the valve-motion (i. e., the eccentric) must move up and down

with the pistons also. This is effected by mounting the eccentric on the crank-pin, instead of on the shaft, as usual. The ports through which the steam enters and leaves the respective cylinders are simply holes in the hollow rod. These are exposed alternately to steam coming from above, through the rod, and to exhaust (also through the rod) downward, according as the corresponding pistons of the valve pass below the holes or above them. Steam enters at the top, through the governor throttle-valve, shown in section, into the steam-chest. The top of the hollow rod, though uncovered, is closed against the steam by the uppermost piston of the valve, which works in the part above the holes. Steam can therefore enter the rod only when the holes are in the steam-chest, as they are when the high-pressure piston is near the upper part of its travel. On commencing the down-stroke the uppermost valve-piston is just passing below the holes, and therefore admits steam into the first or high-pressure cylinder. It rises again, and closes the ports, when the piston has descended about three quarters of its stroke; but the cut-off is effected earlier than this by the holes in the upper part of the hollow rod, leaving the steam-chest and passing through the gland in the cylinder-cover—thus losing their supply of steam. It is evident that the cut-off may be made to take place at any part of the stroke, merely by drilling the holes higher or lower in the rod; the lower they are the earlier in the stroke will they leave the steam-chest. (The same effect is produced by altering the height of the gland in the cylinder-cover.) After cut-off, the steam acts expansively on the high-pressure piston in the usual way. By the time the piston has reached the bottom of its stroke the piston-valve has passed above the ports, and a way is opened from above into the space below the piston, or first receiver. During the up-stroke (effected by the momentum of the fly-wheel only) the steam is merely transferred, practically without change of volume or pressure, into the receiver. At the beginning of the succeeding down-stroke steam passes from the receiver by holes below the upper piston into the hollow rod again, and out by holes above the second piston into the intermediate cylinder. On the next up-stroke the steam exhausts, just as described before, into the second receiver; in the next down-stroke it passes into the low-pressure cylinder; in the next up-stroke it is transferred into the "exhaust-chamber," which is in communication with the atmosphere; but it is not until the third revolution after that in which the steam enters the high-pressure cylinder that it is finally expelled from the engine. The full pressure in the steam-chest is constantly acting upon the valve-piston. This insures that the eccentric-rod shall be kept constantly pressed against the eccentric, as well on the up as on the down stroke. With the steam-pistons the case is different. They are much heavier, and they are all *in equilibrio* during the up-stroke, for there is at that time communication existing between the upper and lower sides of all of them. Special means, therefore, are required for checking their momentum on the up-stroke, so as to keep the connecting-rod brasses truly in "constant thrust." The upward movement of the guide-piston compresses the air contained in the guide-cylinder, until at the top of the stroke a considerable pressure is reached, sufficient to stop the line of pistons, etc., without shock, and without allowing the upper brass to leave the crank-pin. In fact, an air-cushion is substituted for the usual steam-cushion.

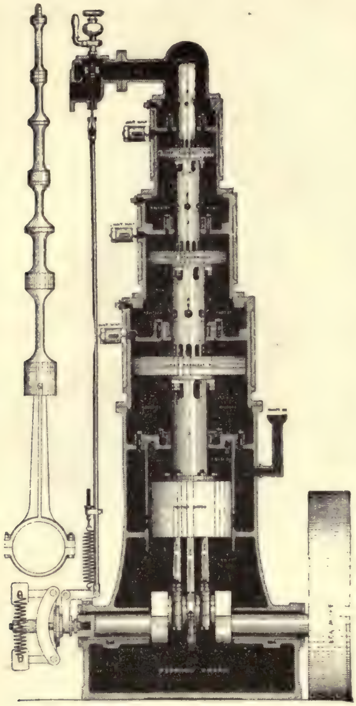


FIG. 62.—The Willans engine.

A test of the Willans engine, by Prof. A. B. W. Kennedy, showed a water-consumption of 19·11 lbs. per indicated horse-power per hour, the engine developing 36·44 horse-power.

The Allis Rolling-Mill Reversing-Engine (Fig. 63) shows a pair of rolling-mill engines built by the E. P. Allis Co. for Carnegie, Phipps & Co.'s Armor Mill in Pittsburg, Pa. The engines are driving a two-roll high train, and are reversed at every pass of the plate in the rolls. The steam cylinders are 40-in. diameter by 54-in. stroke, with Reynolds' Corliss valve-gear without the drop cut-off mechanism; the speed of the engines is controlled by the operator, and is varied in every-day practice from 5 revolutions to 120 revolutions per min. The reversing-gear is handled by a counterbalanced reversing mechanism, operated by steam, which is controlled by a lever on the engineer's platform; from this position he has an unobstructed view of all parts of the engine and roll-train. The journals for the roll-shaft and engine crank-shaft are formed in the same pillow-block, each one having proper means of taking up wear and adjustment. Power from the engine crank-shaft is transmitted to the roll-shaft by means of a pair of shrouded helical tooth steel gears.

The Willard Condensing Engine, made by C. P. Willard & Co., Chicago, is shown in Fig. 64. It differs from an ordinary steam-engine in the fact that while steam is made in the

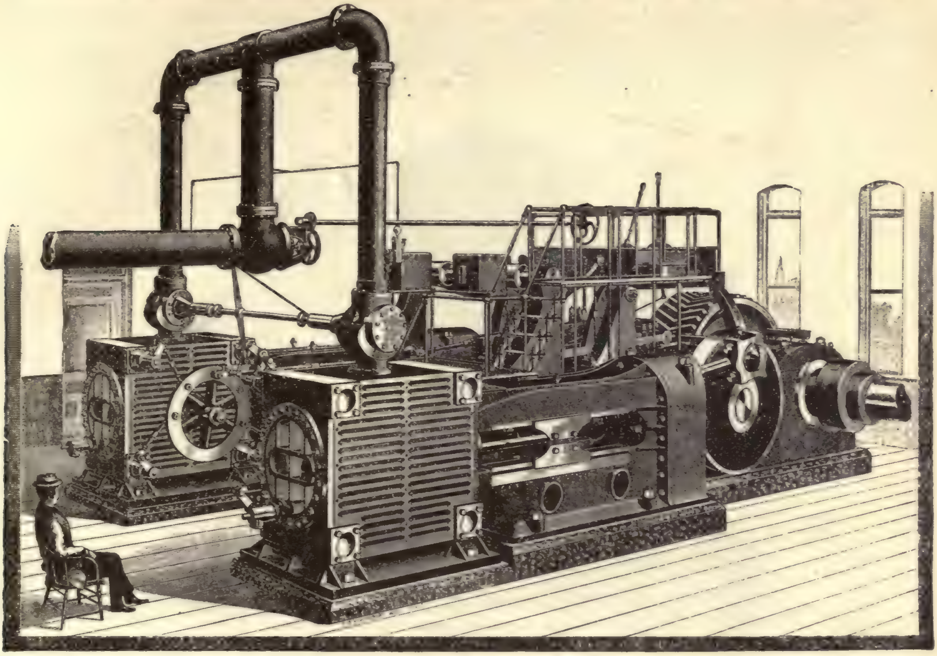


FIG. 63.—Reversing rolling-mill engine.

generator, which is a part of the machine, the only function of the steam is to create, by condensation, a vacuum, which is the motive-power. The engine is double-acting, a vacuum being created alternately at each end of the cylinder. There is no greater than atmospheric pressure in the generator, and there consequently is no danger of explosion. The condensation of the low-pressure steam, by which a vacuum is created, is effected by means of a surface-condenser, which is kept cool by water. Where the engine is to be used in a city or town having public water service, the condenser is placed in the upright iron pocket shown at the back of the engine, and a small stream of water—for the 2-horse-power, ½-in. pipe; for the 4 horse-power, ¾-in. pipe—furnishes an abundant water-supply to keep the condenser cool. The water is admitted at the bottom, and rises to the top, and passes off through an overflow-pipe. Where there is no public water-service, the engine itself operates a small pump, which causes a circulation of water.

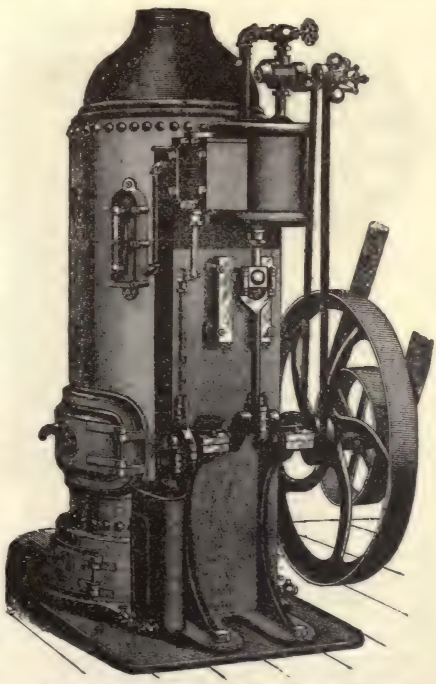


FIG. 64.—The Willard condensing engine.

The cylinder does not require oiling or lubrication, as the low steam used, being very moist, is a sufficient lubricant. The engine requires no attention beyond simply keeping up the fire, and giving the wheel two or three turns when ready to begin operations. There are no exhaust, no steam-gauge, no gauge-cocks, no boiler feed-pump or injector, nor any of these adjuncts of an ordinary steam-boiler. It is practically noiseless, and there is no escape of burned oil or noxious odors. Where power is needed in offices and buildings heated by steam, for running ventilating-fans, printing-presses, or other machinery, the engine may be connected by a pipe with the steam-coil in the room, and run in this way without any generator with the machine; consequently there will be no ashes or dust, and the engine may be started or stopped by opening or closing the valve connecting with the steam-coil.

The Acme Automatic Safety Engine and Boiler, made by the Rochester Machine-Tool Works, Rochester, N. Y., is shown in Figs. 65 and 66.

The engine (Fig. 65) is an upright double-cylinder, single-acting engine, with cranks 180° to each other. The pistons being 1½ times the stroke in length, form their own guides, the

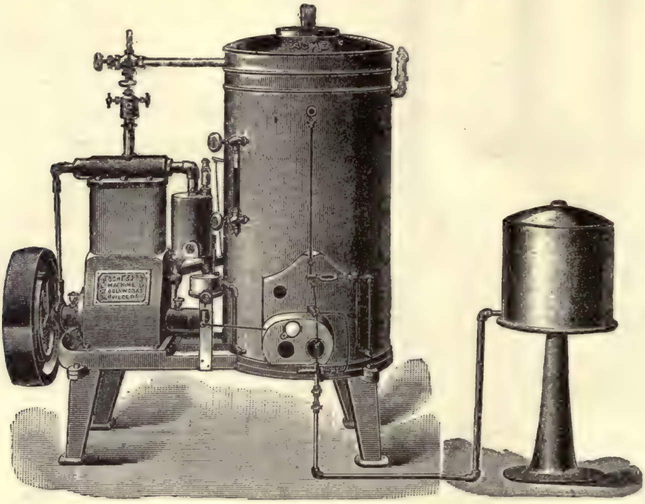


FIG. 65.—The Acme automatic safety engine.

wrist-pins being slightly below the center of the pistons, and the steam-rings above and below the wrist-pins. The valve is of the balanced rocking type, and is placed on the top of the cylinders, the valve-case forming the cylinder-heads. The fly-wheel contains the automatic governor, which regulates the admission of steam to suit the varying loads, by changing the throw of the eccentric that actuates the valve. Lubrication is accomplished by carrying in the crank-case a mixture of oil and water, into which the cranks dip at every revolution.

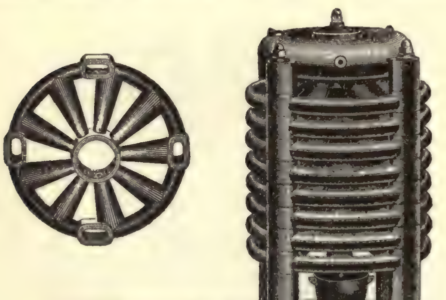


FIG. 66.—The Acme boiler.

The boiler is shown in Fig. 66. It is of the sectional type, the water being carried in a series of rings connected by inclined tubes that break joints. The boiler is double-jacketed to prevent loss of heat by radiation. A large dome on top is used to dry the steam. The water-supply is maintained by a pump worked from the main shaft, which forces the water through a coil-heater, where it is subjected to the effects of the exhaust steam before entering the water-leg of the boiler. The supply of water to the feed-pump is regulated by a ball-float in a case attached to the boiler, which, by means of levers, controls the amount delivered at each revolution of the engine, and may be adjusted to maintain the desired level of water in the boiler under the varying loads to which the engine may be subjected. The fuel is kerosene-oil of 110° to 115° fire-test (this grade giving the best results), atomized by a steam-jet, and controlled by an automatic fire-regulator, that reduces or cuts off entirely the supply of fuel when the steam-pressure reaches the limit at which the regulator is adjusted. This fire is easily controlled, and gives an even and constant supply of steam. The tank containing the oil is placed on a suitable stand, the bottom being as high as or higher than the burner. The oil flows to the atomizer, and is regulated by the cap of the atomizer, as before stated. There is also an automatic self-closing valve located on the oil-pipe, that shuts off the oil when steam is shut off from the atomizer, either by hand or the action of the fire-regulator.

The Shipman Engine and Boiler, made by the Shipman Engine Co., Boston, is shown in Fig. 67. A sectional view of the engine and a side view of the connecting-rod are shown in Fig. 68. The boiler used in engines of from 1 to 6 horse-power is shown in Fig. 69.

This motor is a petroleum-burning steam-engine, for use either on launches or in houses

where a moderate amount of power is required. It is automatic, so that, when once steam has been generated in the boiler, practically no further attention is required beyond that of open-

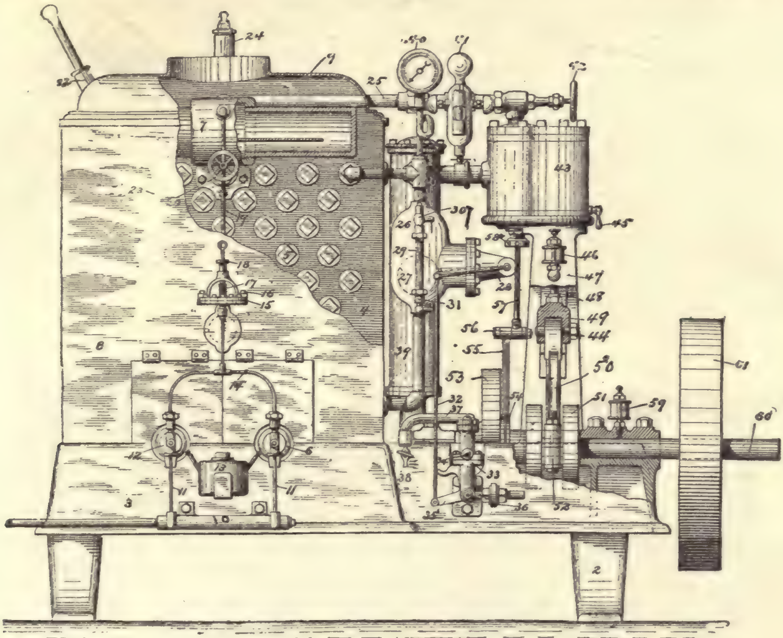


FIG. 67.—The Shipman engine and boiler.

ing and shutting the steam-valve whenever the engine is started or stopped, the fire, speed, and water-feed being so arranged as to attend to themselves. The engine is built upon the same frame as the boiler. This latter is composed of tubes about 18 in. long, which are screwed into a flat, oblong chamber at one end and closed at the other, and is fired externally. Two small aspirators or atomizers, taking steam from the boiler, suck up the petroleum, which is used as fuel, from a chamber below, and drive it into the

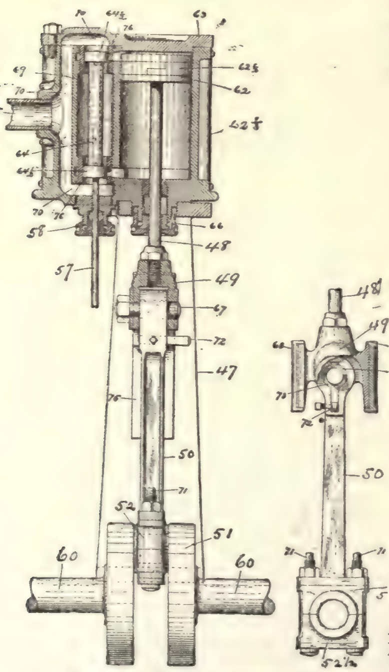


FIG. 68.—The Shipman engine.

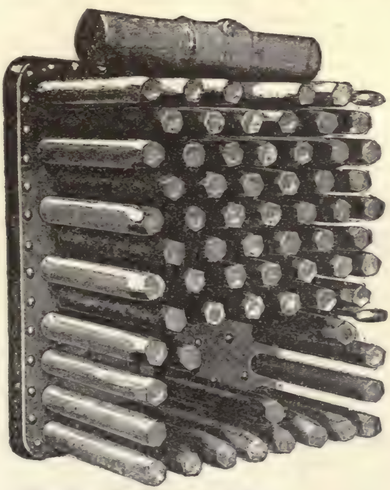


FIG. 69.—The Shipman boiler.

furnaces in the form of a fine spray. A couple of torches ignite this spray as it passes inward, and the flames produced by its combustion rush round

and among the boiler-tubes. The amount of steam and petroleum that is used by the atomizers is regulated by a diaphragm connected to a valve in the steam-pipe that supplies them. This diaphragm is exposed to the steam-pressure on the one side, and is held down by a spring, loaded to a certain pressure, on the other, and moves upward or downward as the steam exerts more pressure than the spring, or *vice versa.* Its movement is conveyed to the valve by means of a rod, and it thus regulates the amount of steam passing at any moment to the atomizers. In this way the fire is made to vary inversely as the pressure in the boiler, and thus keeps the latter constant. The petroleum is stored in a tank at any convenient distance from the motor, and is led to it through a pipe having a regulating valve in it. The water in the boiler is kept at a constant level by means of a float, connected to a tap in the suction-pipe of the pump. This float is placed in a chamber, which is joined to the top and bottom of the boiler, and rises or falls with the level of the water. The movement is conveyed, through a stuffing-box and by means of levers, to the tap in the suction-pipe, which it opens or closes as the water-level changes.

Allis's Hoisting-Engine.—Fig. 70 shows a hoisting-engine built by the E. P. Allis Co., of Milwaukee. The drum is driven by a pair of Reynolds girder-frame Corliss engines. They

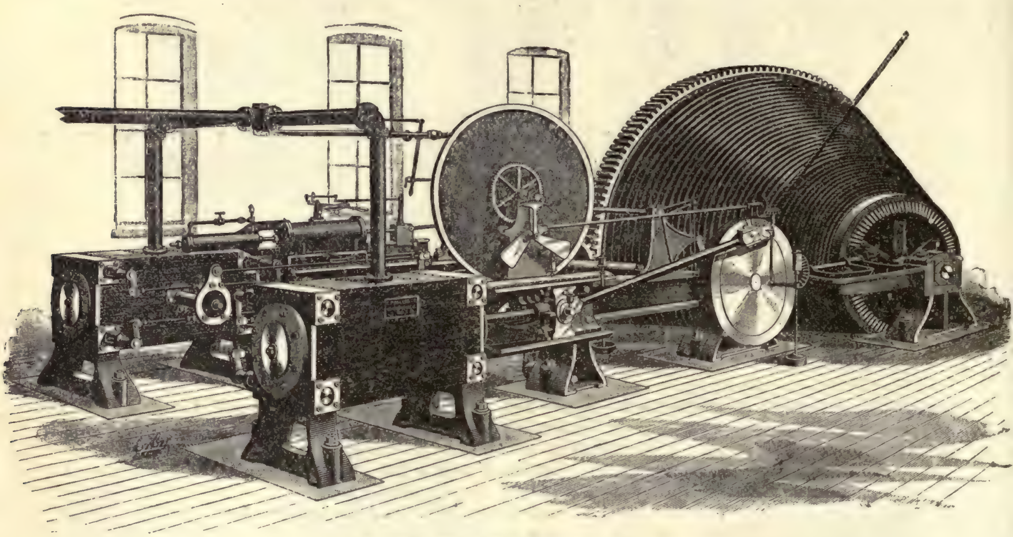
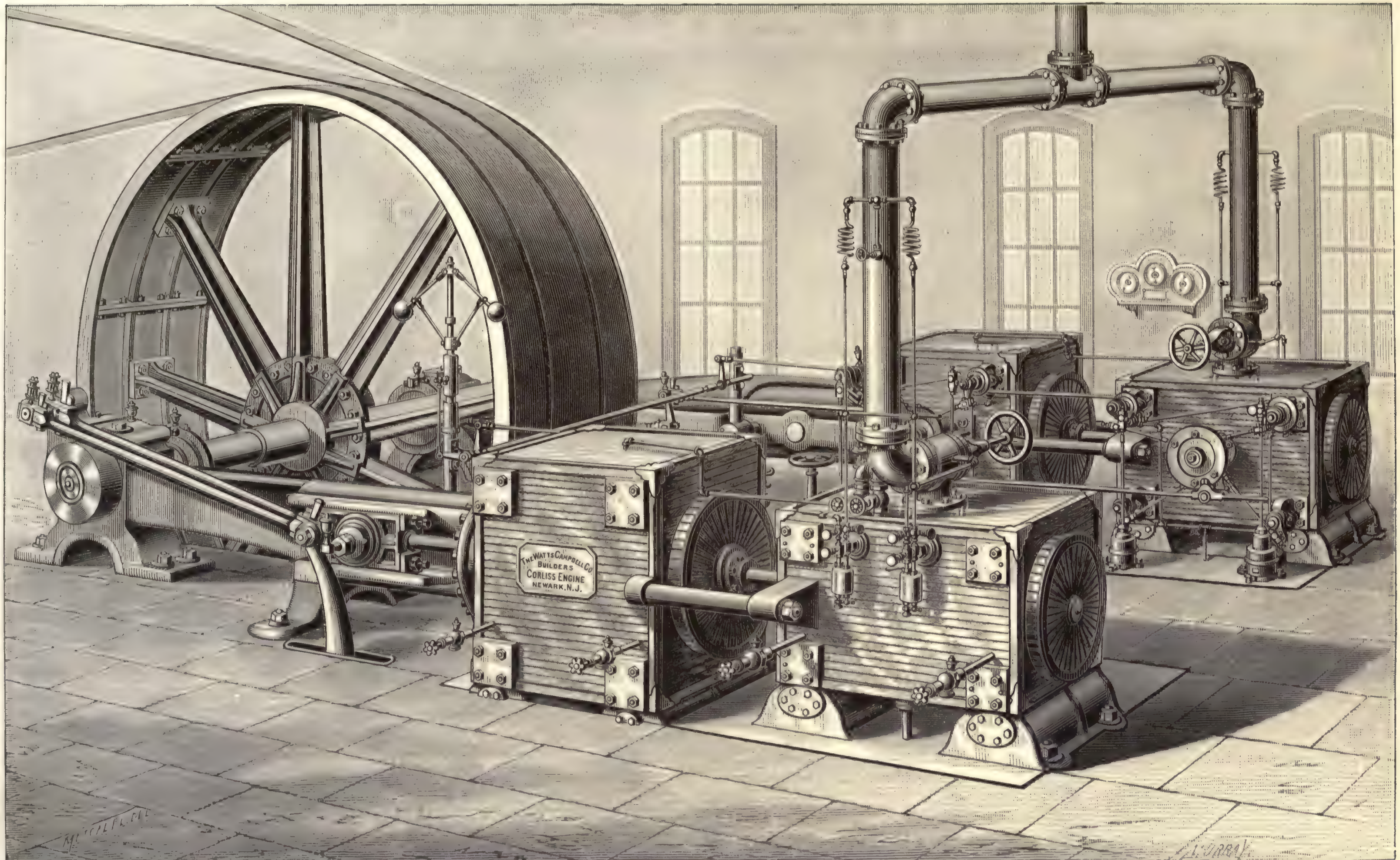


Fig. 70.—The Allis hoisting-engine.

are fitted with improved brake and reversing-gear, etc. The conical rope drum is 18 ft. in diameter at the large end. 8 ft. at the small end, and 12 ft. 9 in. long. The cylinders are 16 in. diameter by 36 in. stroke. Engines of this style are built with different sizes of drums and cylinders to suit the requirements of different locations.

The Dick & Church Tandem-Compound Engine, made by the Phœnix Iron-Works Co., Meadville, Pa., is shown in Fig. 71. It is a two-cylinder compound, both cylinders being overhung, and yet supported from the bed independently of each other, so that they are free to expand and keep in perfect alignment, there being no excessive weight or strain upon either cylinder. The bed of the engine is made in two parts, the lower or sub-base extending the entire length of the machine, and having a hood at the rear end, to which is attached the low-pressure cylinder. On this sub-base, and bolted to it the same as to a foundation, stands the upper bed-plate, on which are the main bearings, guides, and the overhanging high-pressure cylinder. This is perhaps the principal distinctive feature of the engine. It allows each cylinder to expand freely and independently of the other, and either cylinder is easy of acces- for repairs without disturbing the other. The rod seen passing over the cylinders ties the two hoods together, making a rigid construction. The valve mechanism is so arranged that the point of cut-off for both cylinders is under the control of the governor, and varies with the load, thus maintaining a proper distribution of load and temperatures between the two cylinders. The relative points of cut-off can be adjusted by the engineer to suit varying conditions, but once adjusted they vary together by the action of the governor, thus preventing abnormal variations in receiver pressure. The valves are of the double-piston type, working in casings which are readily removable for repairs.

The Watts-Campbell Compound-Condensing Engine.—The full-page engraving represents a pair of engines recently put in the Shrewsbury Mills, at East Newark, N. J., by the Watts-Campbell Co., of Newark, N. J. The engines are tandem-compound, coupled to the shaft at right angles. The high-pressure cylinders are 20 in. diameter and the low-pressure 36 in.; stroke of pistons, 48 in. The engines run at a speed of 64 revolutions per min. Both the high and low pressure cylinders are steam-jacketed, the former with steam direct from the boiler and the latter with the exhaust steam from the high-pressure cylinders.


THE WATTS CAMPBELL CO
BUILDERS
CORLISS ENGINE
NEWARK, N.J.

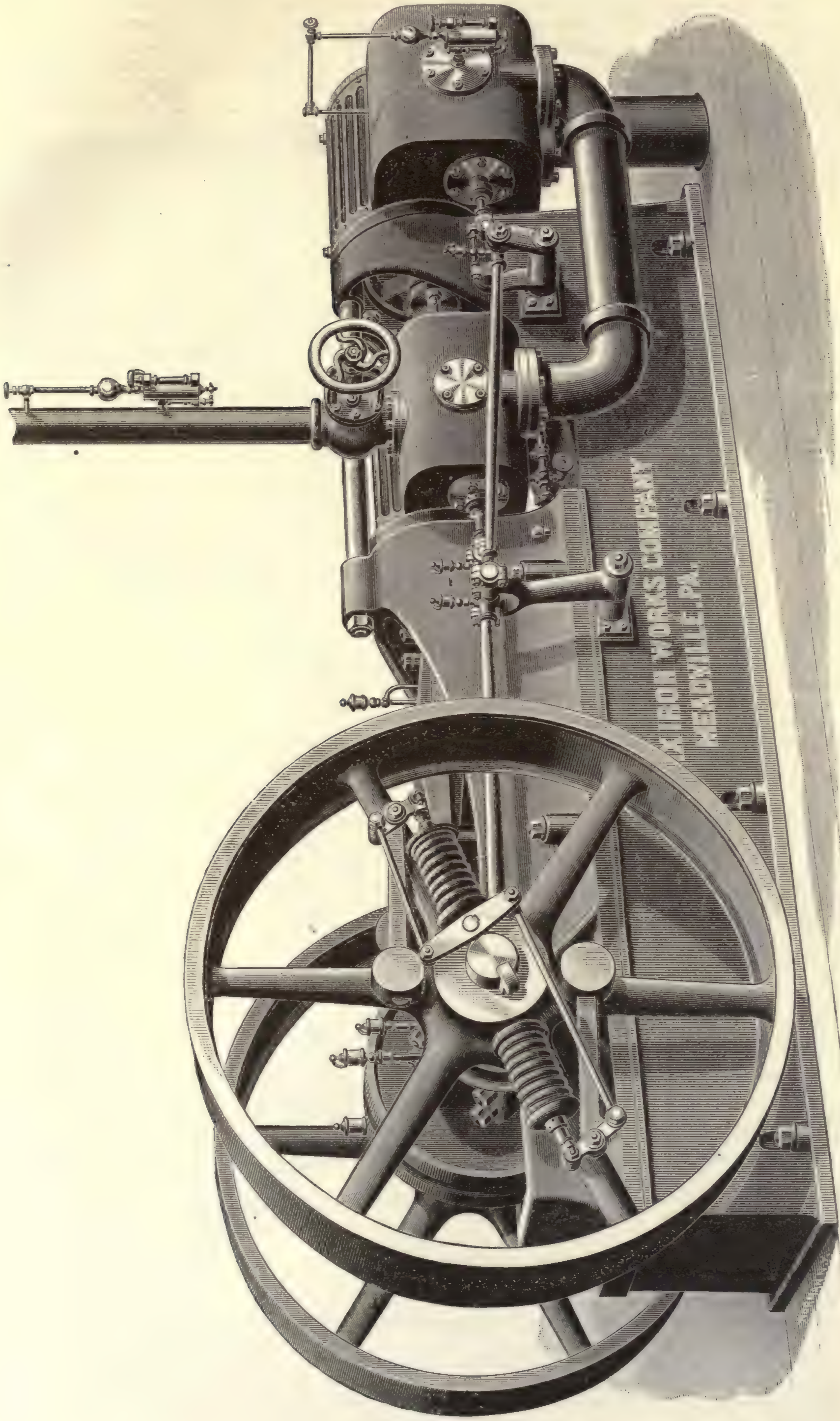


Fig. 71.—The Dick and Church tandem-compound engine.

The exhaust from the high-pressure cylinder passes down through the legs to the receiver, which is cast as part of the low-pressure cylinder and includes the jacket-space of that cylinder. From the low-pressure cylinder the exhaust goes through a large rectangular passage to the condenser, which is situated midway between the two low-pressure cylinders. A small pump returns the water of condensation from the jackets to the boilers. But one air-pump is employed, which is driven by a return rod from one of the crank-pins. The main shaft is 16 in. diameter at the center or wheel fit, and 13 in. at the journals. The band fly-wheel is 25 ft. in diameter, built up in ten segments. It has a face of 6 ft. 2 in., turned for two 28-in. belts and one 10-in. belt. The weight of the fly-wheel is 73,000 lbs. The valve-gear is of the Corliss type, with modifications that have been introduced by the Watts-Campbell Co. The speed is controlled by means of a small fly-ball governor, running at very moderate speed the governor controls admission by eight steam-valves with great precision, without the use of a dash-pot or equivalent attachment to prevent fluctuation. This absence of shock to the governor is mainly due to the action of the releasing gear.

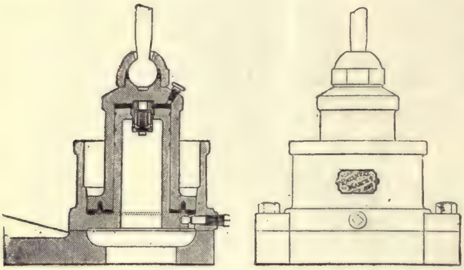


Fig. 72.—Compound condensing engine—details.

Fig. 72 shows the dash-pot used in the Watts-Campbell Corliss engines. The vacuum which serves to close the valve is maintained in the chamber above the central post. As the piston descends, closing the steam-valve, any small quantity of air that may have found its way into this chamber is displaced through the automatic valve shown in the top of post. The cushioning is accomplished in the annular chamber at the bottom. The piston in falling is first partially obstructed in the tapered upper part of the annular chamber; then, as it passes this tapered portion, it is more completely resisted, the only escape for the imprisoned air being such as is provided by the adjusting screw. By means of this screw any desired adjustment of cushion can be made, interposed leathers preventing the parts from striking metal to metal while making such adjustment, or at any time while in operation.

The piston and piston packing used in these engines are shown in Fig. 73. The weight rests upon the center ring, to which the piston and follower are securely attached. When, by wear of the bottom of the center ring and of the cylinder, the piston gets below the center, it can be accurately centered by means of the adjusting screws. This is considered by the builders essential in a horizontal engine, in which, owing to gravity, the bottom of piston and cylinder will be subjected to somewhat the most wear. The center ring carries the weight of the piston, and protects the head and follower from wear. By the Watts-Campbell method of turning the center ring the lower or bearing part is made to exactly fit the bore of the cylinder, the ring being turned out of round to give the requisite clearance. This gives full bearing surface from the start. The packing consists of two small rings, one at either edge of the center ring. These are turned somewhat larger than the bore of the cylinder, then cut and halved together at the joints. When in place they keep in easy contact with the cylinder, without undue friction, compensating for wear by their own elasticity. Light springs are supplied, as shown, which assist in keeping the rings in contact with the cylinder until they are worn out. The governor is connected with a cross-shaft from which small single rods extend to the releasing mechanism of the four cylinders, doing away with the use of the double rods usually employed. In compound engines the connecting rods are six cranks in length. The piston-rods have two different diameters in their length, the difference being sufficient to afford a taper seat for the low-pressure pistons. These pistons are held in place by a key. By disconnecting the rod at the cross-head and moving the low-pressure piston back into the space between the two cylinders the key can be removed: then, by moving the rod forward, the piston can be removed. A noticeable feature in these engines is the fastenings which hold the bed-plates to the pillow-block. In addition to the usual bolts, recesses are cast in the front side of the pillow block and in the front side of the frame against the pillow-block, and a wrought-iron link is shrunk over the parts inclosed by the recesses, binding the pillow-block and frame firmly together.

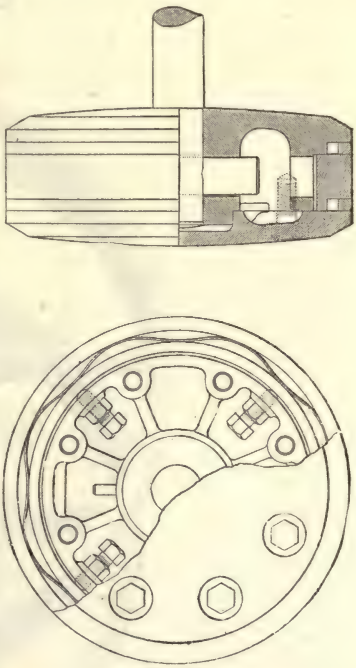


Fig. 73.

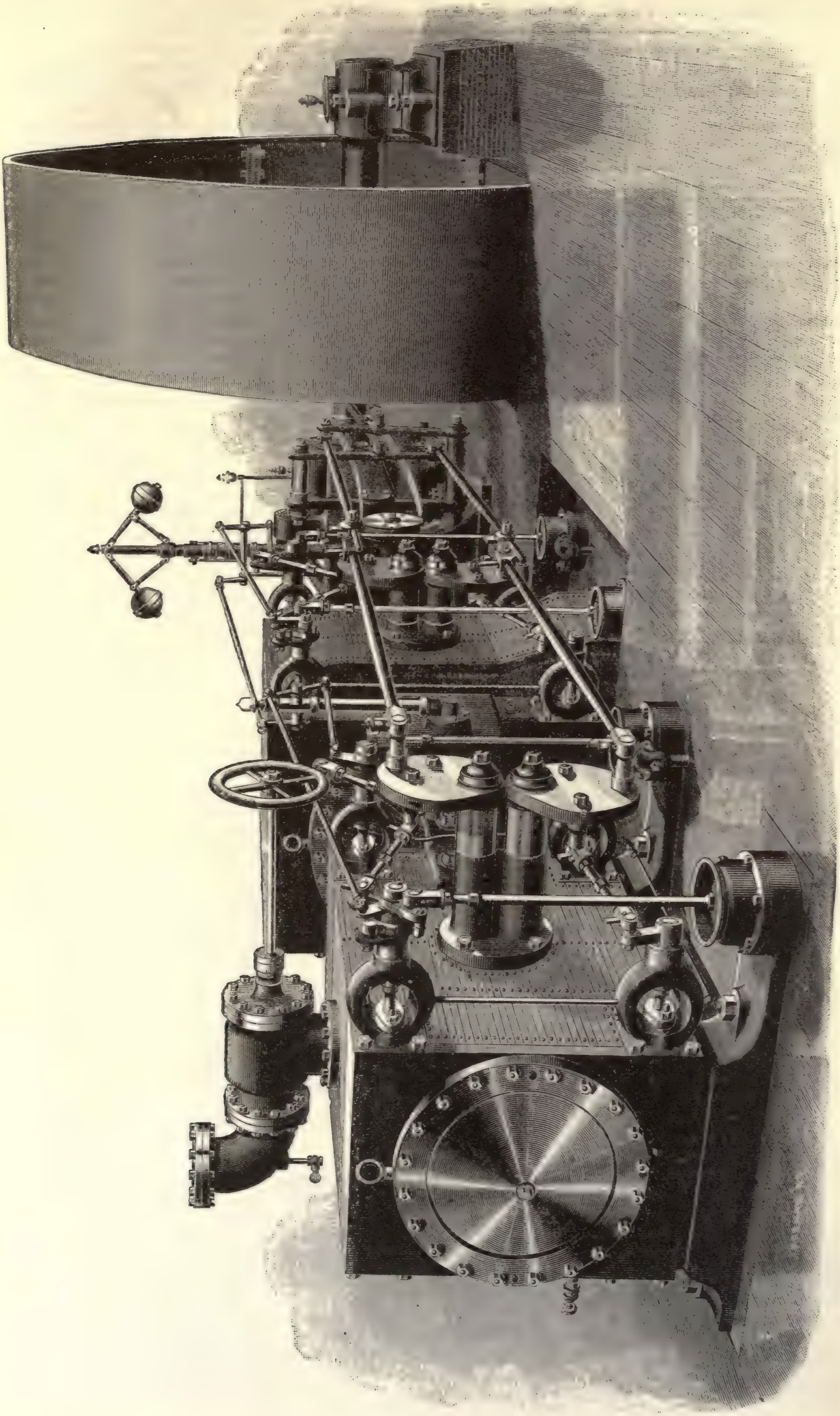


Fig. 74.—The Frick-Corliss engine.

Result of a Four-Days' Trial of the Watts-Campbell Company's Compound-Tandem Engines at the Shrewsbury Mills, commencing May 3d, 7 A. M., and ending May 7th, 7 A. M.

	Lbs. coal used in 24 hrs.	Running time.	Coal used per hour, running time.	Indicated horse-power.	Coal per hour per 1 horse-power.	Revolutions per minute.
May 3d	5,000	10·5 hrs.	476·19	273·09	1·74	64
May 4th	5,500	10·5 "	523·81	295·48	1·77	64
May 5th	5,700	10·5 "	542·86	311·74	1·74	64
May 6th	5,393	10·5 "	513·62	309·81	1·65	64
Average	......	....	514·12	297·53	1·73	....

Constant every-day run ; no coal deducted for banking fires ; no allowance for ashes.

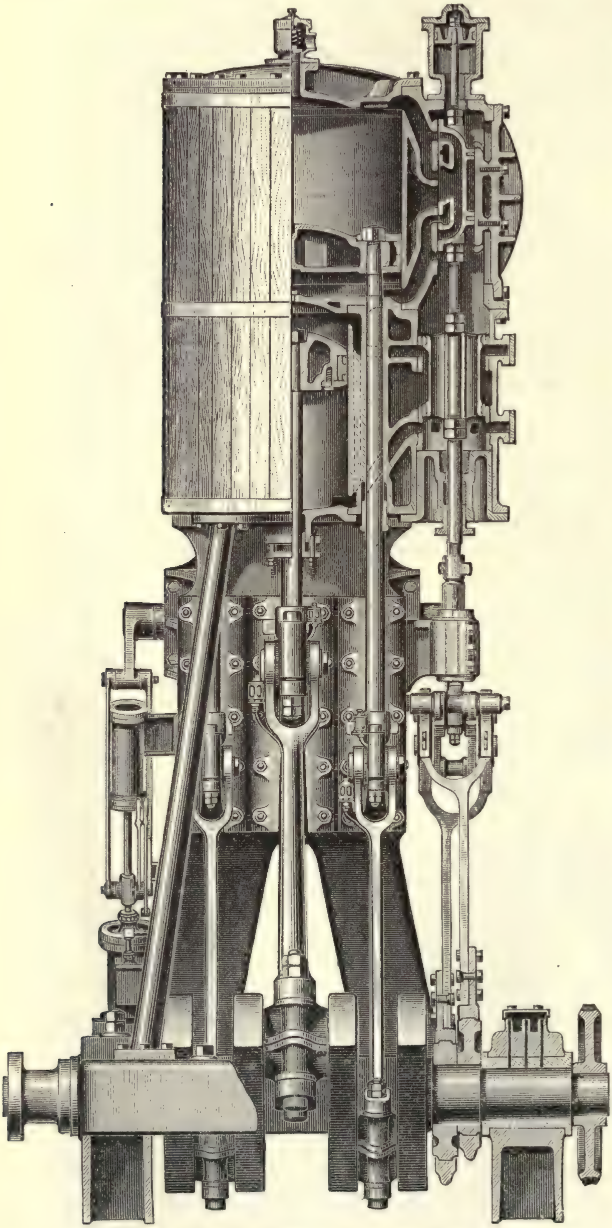


FIG. 75.—The Wells balanced compound engine.

The table above shows the result of a recent test of a pair of these engines, guaranteed to develop 700 indicated horse-power per hour. Upon starting the engines it was found that it would not, at least for some time, be practicable to load them to more than about 300 horse-power; it was then concluded to disconnect one of the pair and test the other, the builders of the engines waiving the right to steam of 110 lbs. pressure, and using but 80 lbs.; two boilers only were used. While the engine was run only through the ordinary working hours—10½—all the coal used during the 24 hours was charged against it; this included coal for banking fires, getting up steam in the morning, etc. The test was continued for 4 days—96 hours—a large number of diagrams being taken from which to compute the power.

The Frick-Corliss Engine.—Fig. 74 (from *Cassier's Magazine*) represents a tandem-compound Corliss engine built by the Frick Co., engineers, Waynesboro, Pa. The valve-gear is of the Corliss type, with constant lever-disengaging motion. One governor controls steam-valves on both high and low pressure cylinders. The wrist-plate motion is driven by two eccentrics, making independent actuation for steam and exhaust valves, and is known as the long-range cut-off. The engine is designed for electric railway and cable work where the variation of the loads is very great. The low-pressure cylinder is 44 in. diameter, high-pressure 30 in. diameter, fly-wheel 25 ft. diameter, 6 ft. face, weight 50 tons. Connection is had

between the high and low pressure cylinders by means of a receiver-pipe, which connects with a flat passage secured on the side of the low-pressure cylinder leading to the steam-chest. The engine illustrated has a nominal capacity of 750 horse-power.

The Wells Balanced Compound-Engine, made by the Wells Engine Co., of New York, is shown in Fig. 75. It is claimed for this engine that it has a natural balance in weight of the two pistons, and their connections, at all angles of the cranks and at all speeds; also a balance of steam pressures. Equal weight being attached to opposite sides of the crank-shaft moving in opposite directions (in the same plane), the thrust of one is perfectly counteracted by that of the other. Steam is admitted simultaneously to the bottom of the high-pressure and to the top of the low-pressure cylinders, and *vice versa*. The force on one cylinder-head is counteracted by an equal force on the other. Hence there can be no strains transmitted to the frame, and thence to the main bearing-boxes. The ascending steam force on the small piston is equaled by a descending steam force on the large piston, which transfers the fulcrum from the main boxes to the crank-shaft, concentrating the whole force in the shaft for useful effect. As clearly shown in the cut, there are three connecting-rods, one transmitting the pressure from the high-pressure cylinder, and the other two connecting with the two piston-rods of the larger cylinder.

Reheater for Compound Engines.—F. W. Dean, of Cambridge, Mass., has recently invented a reheater for use in connection with compound engines for the purpose of superheating the exhaust steam from the high-pressure cylinder before it enters the low-pressure cylinder. Fig. 76 shows a vertical section elevation, and Fig. 77 a sectional plan. The cylinder A is of cast iron, and is provided at the center with an inwardly projecting T-shaped annular rib, A^1.

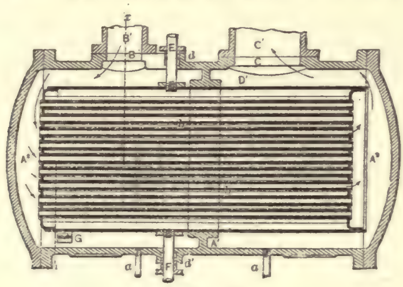


FIG. 76.

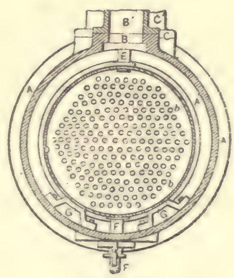


FIG. 77.

On one side is formed a passage, B, communicating with the exhaust-pipe B^1 of the high-pressure cylinder, and a passage C opening into the pipe C^1, through which the steam passes to the low-pressure cylinder after having been reheated. The ends of the cylinders are closed by the heads A^2 A^3, and into its under side are screwed two drain-pipes a. A copper or steel cylinder D has its ends closed by heads which serve as tube-sheets to support the series of tubes b, which are inserted in the usual way—that is, by expanding their ends. Live steam enters through the pipe E and passes out through the pipe F. The construction of the cylinders A and D and the heads A^2 A^3 is such that the exhaust steam from the high-pressure cylinder surrounds the cylinder D at the left of the partition-rib A^1, passes through the tubes, surrounds the right-hand half of the inner cylinder, and then passes through the pipe C^1 to the valve-chest of the low-pressure cylinder. In the mean time the interior of the cylinder D has been filled with live steam from the boiler which surrounds all the small pipes, imparting a portion of its heat to them and to the shell of the inner cylinder, which is taken up and absorbed by the exhaust steam.

Joy's Valve-Gear.—It has constantly been an object with inventors to get rid of the complications of the two eccentrics, link, etc., required for an expansion and reversing gear. Several successful gears have recently been brought out, in which the valve is driven from some reciprocating part of the engine. One of the best known of these is the Joy valve-gear, which has been largely used both for locomotive and marine engines. Figs. 78 and 79 illustrate a simple form of this gear applied to a horizontal stationary engine. A vibrating rod or link B is attached at one end to a point A, near the middle of the connecting-rod; while the lower end is joined to the radius-rod C, which compels B to move in a vertical plane. To a point D in the link B is jointed the end of the long arm of a lever E F, of which the end of the small arm works the valve-rod G, and the fulcrum F is attached to a block which slides in the curved slot J. This slot is formed in a disk, the center of which is the position of the fulcrum F when the piston is at either end of its stroke. The radius of the slot is equal to the length of the valve-rod G.

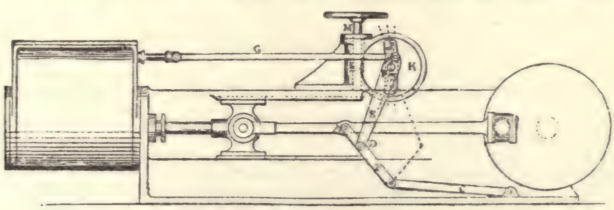


FIG. 78.

The disk can be made to rotate through an arc by means of the worm and wheel shown. Thus the slot can be inclined to either side of the vertical. The slot allows the fulcrum of the lever to move up and down with the motion of the point A of the connecting-rod. The forward or backward motion of the engine and the rate of expansion are controlled by inclining the slot to one or other side of the vertical, the central position corresponding with mid-gear. If the end D of the lever were attached direct to the connecting-rod, the motion of the fulcrum F about the center of the slot would not be symmetrical, and the result would be that the cut-off would be unequal in the two strokes. This error is corrected by attaching the end of the lever to the point D of the vibrating link; for, while the point A on the connecting-rod describes a nearly true ellipse, as shown in Fig. 81, the point D describes a bulged figure, and the amount of the bulge is so regulated as to correct the unequal motion of the fulcrum above and below its central position. It is obvious that by shifting the point D the amount of the bulge may be altered, and thus the error may be corrected too little or too much, and by taking advantage of this circumstance a later cut-off may be given to either end of the cylinder, if found desirable.

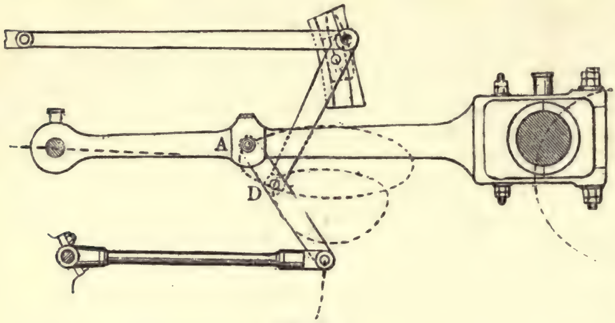


FIG. 79.

Marshall's Valve-Gear, which has recently been fitted to a large number of marine engines, is shown in Fig. 80. In this system only one eccentric is used, the end of the eccentric rod being attached to a rod hung from a pin on the reversing-shaft lever R, by which it is constrained to move in an arc of a circle inclined to the center line. To an intermediate point P in the eccentric-rod a connecting link is attached, which communicates the necessary motion to the slide-valve rod. By adjusting the position of the reverse lever R any desired degree of expansion can be obtained, or the engines reversed, as required. There are few working parts, and distribution of steam both for full power and for expansive working is satisfactory.

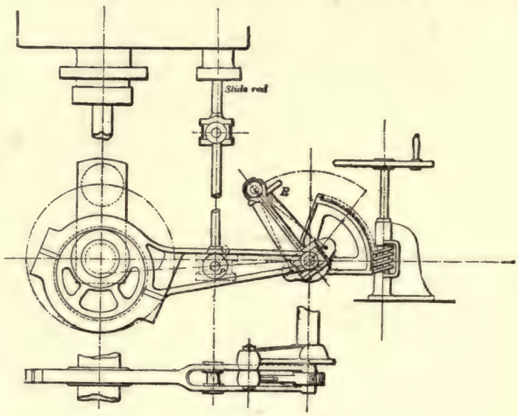


FIG. 80.

II. ENGINE TRIALS AND PERFORMANCES.—*Economy of Small Engines.*—At the Plymouth show of the Royal Agricultural Society of England in 1890 a series of tests as made of small engines, the competition being restricted to those below 5-brake horse-power. Three engines were tested, with the results shown in the following table:

SUMMARY OF RESULTS.	Simpson, Strickland & Co., Dartmouth.	E. R. and F. Turner, Ipswich.	Adams and Co., Northampton.
BOILER.			
Water evaporated per lb. of coal from feed temperature.................lbs.	8·726	7·65	5·978
Equivalent evaporation from and at 212°..................................	10·42	9·065	7·136
Efficiency of boiler..	0·689	0·599	0·528
Thermal units transmitted per min. through each sq. ft. of heating surface..	59·42	185·4	150·1
Coal burned per sq. ft. of grate per hour..................................lbs.	9·635	16·65	12·75
Water evaporated per sq. ft. of heating surface per hour................ "	3·09	9·71	7·80
ENGINE.			
Piston-speed in ft. per min...	298·1	263	240·3
Indicated horse-power	5·641	5·175	6·201
Brake horse-power...	5·042	3·997	5·003
STEAM.			
Steam used per indicated horse-power per hour..............................	35·75	64·73	57·75
COAL.			
Per indicated horse-power per hour ....lbs.	4·099	8·461	9·66

See *Engineering* of Nov. 14, 1890, for comments on these results.

Triple-Expansion Engines, Performances of Stationary.—Experiments were made at Augsburg on Oct. 9, 10, and 11, 1889, by Prof. M. Schröter, of Munich, on a horizontal triple-expansion engine (Sulzer), indicating 200 horse-power, and constructed by the Augsburger Machinen-Fabrik for driving part of their works. The experiments were very carefully carried out; the chief results of one of five trials are given in *Engineering*, Dec. 5, 1890. Prof. Schröter's paper appeared in the *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xxxiv, p. 7. In it he gives full particulars of all his five experiments, the second of which has been here summarized. Each of them lasted from five to six hours. Three were made with ⅕ cut-off in the first cylinder and two with 0·3 cut-off, and all with steam in the jackets. The mean result in pounds steam per indicated horse-power per hour of experiments 1, 2, and 3 is 12·58 lbs.; the mean of the two others is 12·83 lbs. per indicated horse-power per hour.

The summary above referred to is as follows:

Steam-engine experiment made Oct. 10, 1889. Triple engine.

Type: Horizontal, two cranks at right angles, one crank with first and second cylinders tandem, and other for third cylinder.

Diameters of cylinders: 11·10 in., 17·75 in., 27·61 in.

Stroke: 39·37 in., 39·37 in., 39·68 in.

Condensing.

Kind of condenser: Jet.

Steam-jacketed very completely.

Three cylinders jacketed.

Covers jacketed.

Two receivers jacketed, all with boiler steam.

Kind of valves: Four Sulzer valves to each cylinder.

Clearance assumed: Five-per-cent cylinder 1, 4-per-cent cylinders 2 and 3.

Results of Test.

Duration	5 h. 6 m.
Pressure of steam, saturated or superheated	156 lbs.
Cut-off in first cylinder	⅕.
Vacuum in condenser (in.)	28⅛.
Revolutions per min.	70·2.
Piston-speed per min.	460 ft.
Indicated horse-power	198.
1st cyl., 57·87; 2d cyl., 41·25; 3d cyl., 98·91.	
Water as steam from boiler per indicated horse-power per hour, deducting water condensed in steam-pipe	12·2 lbs.
Steam condensed in jacket (included in above)	20 per cent of feed-water.

2·2 per cent in 1st cyl., 6·4 per cent in 2d and 1st receiver, 10·7 per cent in 3d and 2d receiver.

		Per hour.	Per I. H.-P. per hour.
Water from inside of receiver	I	= 68·8 lbs.	= 0·347 lbs.
" " "	II	= 0	
Jacket-water	Cyl. I	= 68·36 "	= 0·345 "
	" II and receiver I	= 155·2 "	= 0·784 "
	" III " II	= 258·8 "	= 1·307 "

At ⅕ cut-off in first cylinder two experiments were made, which gave in feed-water 12·60 lbs. and 12·92 lbs. per indicated horse-power per hour. At 0·3 cut-off in first cylinder two experiments were made, which gave in feed-water a mean of 12·83 lbs. per indicated horse-power per hour. 2·9 per cent of water was separated from end of steam-pipe, deducted from total feed, and excluded from the above results of feed-water.

Two-Cylinder vs. Three-Cylinder Engine.—A Wheelock triple-expansion engine, built for the Merrick Thread Co., of Holyoke, Mass., is constructed so as to cut the intermediate cylinder out of the circuit and run the high-pressure and low-pressure cylinders as a two-cylinder compound, using the same conditions of initial steam-pressure and load. The diameters of the cylinders are 12, 14, and 24$\frac{1}{32}$ in., the stroke of the first two being 36 in. and that of the low-pressure cylinder 48 in. The results of four tests reported by S. M. Green and G. I. Rockwood in *Trans. A. S. M. E.*, vol. xiii, show that when running as a two-cylinder compound, with steam-pressure 142 lbs., 79 revolutions per min., indicating 187 and 181 horse-power, the consumption of dry steam per horse-power per hour was respectively 13·06 and 12·76 lbs., and when running as a triple-expansion engine with the same pressure of steam and number of revolutions, developing 199 and 178 horse-power, the steam consumption was respectively 12·67 and 12·90 lbs. These tests indicate that there is but a trifling difference in economy between a two-cylinder and a triple-expansion engine when both are run under the same conditions as to pressure, load, and rate of expansion.

For other tests of triple-expansion engines, see *Engineering*, Nov. 28, 1890; also *Trans. A. S. M. E.* vol. xii.

Dimensions and Ratios of Cylinder Areas in Compound Engines.—Mr. Charles T. Main, in a paper on The Use of Compound Engines for Manufacturing Purposes (*Trans. A. S. M. E.*, vol. x), gives a table showing the dimensions of engines used in several large mills in New England and in a few small ones in Europe, as follows:

LOCATION.	Designer or builder.	DIAMETERS OF CYLINDERS IN INCHES.		Length of stroke in inches.	Relative areas of cylinders.	Lbs. water per I. H.-P. per hour.	Lbs. coal per H.-P. per hour.
		High pressure.	Low pressure.				
Plymouth Cordage Co.......	Corliss	30	60	72	1 to 4	......	.....
Sewell and Day	Reynolds......	22	44	60	1 " 4	......	.....
Globe Yarn Mills...........	Wetherill......	24	48	60	1 " 4	......	.....
Dyerville Man'f'g Co.......	W. A. Harris..	16	32	48	1 " 4	......	.....
Amoskeag " "	Wright........	30	56	48	1 " 3·48	......	.....
Wetamoe Mills.............	Wetherill......	26	48	60	1 " 3·41	16·28	.....
Atlantic Delaine...........	Corliss	24	44	72	1 " 3·36	......	1·69
Ann & Hope Mills..........	"	22	40	60	1 " 3·31	......	.....
Nourse Mill................	"	20	36	72	1 " 3·24	......	1·63
Bristol Cotton Mill.........	Reynolds......	18	32	48	1 " 3·16	......	.....
Lower Pacific Mills.........	Corliss	32	44	72	1 " 1·89	......	.....
Province of Naples.........	Sulzer Bros...	21·62	40·1	59·1	1 " 3·44	14·073 14·586	1·478 1·566
" " "	" "	24	40	59·1	1 " 2·78	13·68 14·81	1·436 1·52
Faromer, Bohemia.........	Bromorsky & Schultze	25	43	49¼	1 " 2·96	15·774	.....
Mossley, near Manchester, England.	Goodfellow & Matthews ...	24	52	72	1 " 4·69	18·84	1·87

He recommends the following ratios of areas of cylinders:

Ratios of Areas of Cylinders.

RECEIVER-PRESSURE.	BOILER-PRESSURE.	
	100 lbs.	125 lbs.
5 lbs.	1 to 3·50	1 to 4
10 "	1 " 3·75	1 " 4·25
15 "	1 " 4	1 " 4·50

For boiler-pressures above 125 lbs. the triple-expansion engine should be used to get the full benefit of the higher pressures.

See also a paper on the Cylinder Ratios of Triple-Expansion Engines by Prof. Jay M. Whitham, *Trans. A. S. M. E.*, vol. x.

Relative Commercial Economy of Compound and Triple-Expansion Engines.—Prof. J. E. Denton, in a paper read at the meeting of the American Association for Advancement of Science in August, 1891, gives the following table and deductions to show the relative commercial economy of the compound and triple type for the best stationary practice. The table is based on the tests of Prof. Schröter, of Munich, of engines built at Augsburg, and those of George H. Barrus on the best plants of America, and of detailed estimates of cost obtained from several first-class builders:

STEAM-PLANTS OF 500 INDICATED HORSE-POWER.	TRIP MOTION, OR CORLISS ENGINES OF THE TWIN COMPOUND RECEIVER-CONDENSING TYPE, EXPANDING 16 TIMES. BOILER-PRESSURE, 120 LBS.		TRIP MOTION, OR CORLISS ENGINES OF THE TRIPLE-EXPANSION FOUR-CYLINDER RECEIVER-CONDENSING TYPE, EXPANDING 22 TIMES. BOILER-PRESSURE, 150 LBS.	
	Lbs. water per hour per H.-P., by measurement.	Lbs. coal per hour per H.-P., assuming 8·5 lbs. actual evaporation.	Lbs. water per hour per H.-P., by measurement.	Lbs. coal per hour per H.-P., assuming 8·5 lbs. actual evaporation.
Best performance..................	13·6	1·60	12·56	1·48
Probable reliable performance.....	14	1·65	12·80	1·50

Increased cost of triple-expansion plant per horse-power, including boilers, chimney, heaters, foundations, piping, and erection.. $4 50

	Plant used 300 days, 10 hours per diem.	Plant used 360 days, 24 hours per diem.
Total annual expense for coal at $4 per ton. Compound plant.................	$9 90 h.-p.	$28 50 h.-p.
" " " " " Triple plant.......................	9 "	25 92 "
Annual saving of triple plant in fuel...	90 "	2 60 "
Annual interest at 5 per cent on $4.50.......................................	$0 23	$0 23
Annual depreciation at 5 per cent on $4.50...................................	23	23
Annual extra cost of oil, 1 gal. per 24-hour day, at $.50, or 15 per cent of extra fuel cost	15	36
Annual extra cost of repairs at 3 per cent on $4.50 per 24 hours................	06	14
	$0 67	$0 96
Annual saving per h.-p...	$0 23	$1 64
Or, the saving in per cent of the annual cost of fuel per h.-p. of the compound is	2·3%	5·8%

See also paper by Mr. Robert Wyllie, *Trans. Inst. of Mechl. Engrs.*, Oct., 1886.

THE INFLUENCE OF STEAM-JACKETS.—Numerous tests of the efficiency of the steam-jackets of the Pawtucket (R. I.) pumping-engine were made by Profs. J. E. Denton and D. S. Jacobus, and Mr. William Kent, and recorded in the *Trans. A. S. M. E.*, vols. xi and xii.

Mr. Kent's conclusions, based upon these tests, are as follows: In the Pawtucket pumping-engine the use of the jackets gives a saving of between 1 and 4 per cent, but they do not lead to any more general conclusion than that jackets may be expected to give this saving in a cross-compound Corliss engine of 140 horse-power, running at about 50 revolutions per min., supplied with dry steam of 125 lbs. gauge-pressure, and cutting off at about one quarter stroke in the high and one third stroke in the low pressure cylinder. Before this conclusion can be expanded to apply to other engines, there should be tests made with equal precautions and refinements to those made with the Pawtucket engine, on such other engines, with different dimensions and different conditions, such as pressure of steam, moisture or superheat in the steam, speed of revolution, number of expansions in the two cylinders, etc. In the discussion of Mr. Kent's paper it was shown that the results obtained in the Pawtucket engine confirm those which have been recently found in marine engines. (See Thurston's *Manual of the Steam-Engine;* also a paper by Mr. Joseph Wright in *Proc. Inst. of Mech. Engrs.*, February, 1887.)

FRICTION OF ENGINES.—Prof. R. H. Thurston, in papers read before the American Society of Mechanical Engineers (*Trans.*, vols. viii, ix, x), has called attention to the fact that the variation of load in steam-engines is not productive either of the method or of the amount of engine-friction that has been commonly assumed by earlier authorities on that subject.

Later experiments by Prof. R. C. Carpenter and Mr. G. B. Preston, of Sibley College, lead to the conclusions, as stated by Prof. Thurston, that the most important item of friction waste, in every instance, is that of lost energy at the main bearings. In every case it amounts to one third or one half of all the friction resistance of the engine, or from about 5 to 10 per cent of the whole power of the engine in the cases examined, the higher figures being given by the condensing, the lower by the non-condensing engines, except that the first experiment, with the straight-line engine, gives as high a figure as the condensing engines—a fact due, however, rather to the exceptionally low total than to exceptionally high friction on the main shaft. The second highest item is, in all cases apparently, the friction of piston and rod, the rubbing of rings and the friction of the rod-packing. This is a very irregular item, and amounts to from a minimum of 20 per cent to some higher but undetermined quantity. The third item in order of importance is the friction of valve, in the case of the engines having unbalanced valves. This is seen to be hardly a less serious amount than the frictions of shaft and of piston. But it is further seen at once that this is an item which may be reduced to a very small amount by good design, as is evidenced by the fact that, in the straight-line engine, it has been brought down from 26 to 2·5 per cent by skillful balancing. Ninety per cent, therefore, of the friction of the unbalanced valve is avoidable or remediable. The importance of this fact is readily perceived when it is considered that not only is it a serious direction of lost work and wasted power and fuel, but that the ease of working of the valve is a matter of supreme importance to the effective operation of the governing mechanism in this class of engines. No automatic engine can govern satisfactorily when the valve is unbalanced, and is certain to throw much load on the governor. The frictions of crank-pin, of cross-head, and of eccentrics, are the minor items of this account; they are comparatively unimportant.

Cylinder Condensation in Stationary Engines—Single-Cylinder.—Mr. G. H. Barrus gives the following figures representing the proportion of feed-water which, with tight valves and piston, will be accounted for by the indicator at different cut-offs, for factory-engines as commonly used with unjacketed cylinders exceeding 20 in. in diameter, supplied with dry but not superheated steam. In many cases, however, leakage through the valves or by the piston increases materially the percentage of waste; so that if the wastes in this table are exceeded it can be inferred at once, unless the engine speed is extremely low, that the excess is due to this cause:

Percentages of Loss by Cylinder Condensation.

Percentage of stroke completed at cut-off.	Percentage of feed-water consumption accounted for by indicator-diagrams.	Percentage of feed-water consumption due to cylinder condensation.
5	58	42
10	66	34
15	71	29
20	74	26
30	78	22
40	82	18
50	86	14

In ordinary practice there is a rough rule, agreeing nearly with that above, applicable between 2½ and 5 expansions, slight leakage only; it may be stated thus: The total amount of loss due to condensation per stroke is a constant amount equal to 25 per cent of the feed-water employed at quarter cut-off.

See also a paper by Major T. English, R. E., in *Proc. Inst. M. E.*, September, 1887. Prof. R. H. Thurston, in his *Manual of the Steam-Engine*, compares the statements of different authorities on this subject.

GENERAL DATA.—*Dimensions of Important Parts of Corliss Engines.*—James B. Stanwood, in his paper on Stationary-Engine Practice in America, *Engineering*, June 12, 1891, gives the following table:

Dimensions of Important Parts of Corliss Engines.

	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Diameter of cylinder	10	12	14	16	18	20	22	24	26	28	30
Main bearing, diameter	4 15/16	5 15/16	6 15/16	7 15/16	8 15/16	9 15/16	10 15/16	11 15/16	12 15/16	13 15/16	14 15/16
Main bearing, length	10	12	14	16	18	20	20	22	22	26	26
Steam-pipe, diameter	3	3 1/2	4	4 1/2	5	6	6	7	7	8	9
Exhaust-pipe, diameter	3 1/2	4	5	6	6	7	8	9	9	9	10
Steam-ports, width	3/4	3/4	13/16	7/8	15/16	1 1/16	1 1/8	1 3/16	1 3/8	1 1/2	1 15/16
Steam-ports, length	9	11	12 1/2	14 1/2	16 1/2	18 1/2	21	23	25	27	29
Exhaust-ports, width	1 3/16	1 3/16	1 5/16	1 7/16	1 9/16	1 3/4	1 7/8	2	2 1/8	2 5/16	2 1/2
Exhaust-ports, length	9	11	12 1/2	14 1/2	16 1/2	18 1/2	21	23	25	27	29
Crank-pin, diameter	2 7/16	2 15/16	3 7/16	3 15/16	4 7/16	4 15/16	5 7/16	5 15/16	5 15/16	6 7/16	7 7/16
Crank-pin, length	3 1/4	3 3/4	3 3/4	4 3/8	5	5 5/8	5 3/4	7 1/2	7 1/4	9	9
Cross-head pin, diameter	2 7/16	2 15/16	2 15/16	3 15/16	3 15/16	4 15/16	4 15/16	5 15/16	5 15/16	6 7/16	6 7/16
Cross-head pin, length	3 1/4	3 3/4	3 3/4	4 3/8	4 3/8	5 1/8	5 1/8	5 1/4	5 1/2	6 1/4	6 [illegible]
Valve-chamber, diameter	3 1/2	3 3/4	4 1/8	4 1/2	5	5 1/4	6	6 1/2	7	7 1/2	8 [illegible]
Valve-stem, diameter	1 3/16	1 5/16	1 5/16	1 7/16	1 9/16	1 11/16	1 11/16	1 15/16	1 15/16	2 3/16	2 3/16
Piston-rod, diameter	1 15/16	2 3/16	2 7/16	2 15/16	3 3/16	3 7/16	3 15/16	4 3/16	4 7/16	4 [illegible]	4 [illegible]

Limit of Expansion in a Two-Cylinder Compound Engine.—John G. Mair (*Proc. Inst. M. E.*, February, 1887) says, with regard to the number of expansions that could advantageously be made in an ordinary two-cylinder compound engine, the following were the results of experiments that he had made with a pumping-engine, raising the boiler-pressure from 60 up to 120 lbs. per sq. in. above atmosphere while working throughout at practically the same speed:

Boiler-pressure, lbs. per sq. in. above atmosphere	60	80	100	120
Number of expansions	9·2	13·2	14·1	13·7
Thermal units used per indicated horse-power per minute	334	327	325	330

These figures showed that, after obtaining somewhere about 10 or 12 expansions, there was no economy in going to any higher expansion with two cylinders, as the saving in heat expended was not sufficient to make up for the increased frictional loss due to the larger cylinders required.

Water-Consumption of Different Types of Engine.—The following are common figures for the usual performance of stationary engines used in electrical work in 1890 (Thurston's *Manual of the Steam-Engine*):

High-speed, single-cylinder	35 to 40 lbs. water.
" " compound, non-condensing	25 to 47 " "
" " " condensing	19 to 21 " "
" " triple-condensing	16 to 17 " "
Corliss single, non-condensing	27 to 29 " "
" compound, condensing	15 to 16 " "
" triple	13 to 14 " "

In common practice, with 150 lbs. steam, the temperature being equalized, the ratios of cylinder volumes in the triple-expansion engine are about 1 : 2·5 : 7·5.

Possible Improvements in the Steam-Engine.—Prof. Thurston says that comparison of results of experience leads to such final conclusions as follows:

1. Experiment, experience, and the philosophy of the steam-engine combine to indicate that the limit of possible advance in their economical application is now so nearly approached that further progress must be expected to be both slow and toilsome.

2. That the range left for such further improvement upon the best and most efficient of existing engines is probably small, and the difficulties arising in the attempt to reduce it are increasing in a higher ratio than progress in its reduction.

3. That, while wasteful engines may be improved by various expedients, including the substitution of other working fluids than steam, either wholly or partly, no other vapor has yet been found to give an economical performance exceeding on the whole, or even equaling, that obtained with the best steam-engines.

ENSILAGE MACHINERY. The introduction of the silo, a roofed bin or pit for storing and preserving under fermentation green corn, clover, and other forage plants, chopped fine and closely laid in, with frost and extraneous moisture excluded, is vastly augmenting the resources of the farmer for winter forage for live-stock. The gravity of the mass thus confined causes it to settle, and its acetous nature causes it to ferment and form a firm cake known as ensilage. This is taken out only so fast as it is required for feeding by means of a long upright opening or doorway in the side of the silo. For convenience, the silo is most often erected inside one end of the cattle-house, although it may be built separate if preferred.

Silo-Construction.—Several prevailing methods of silo-construction, recommended by E. W. Ross & Co., of Springfield, Ohio, are indicated in Figs. 1 to 6. Fig. 7 shows the best silo-doorway yet devised, closed with blocks *D*. The drawing shows the inside of the silo-wall. The pressure of the ensilage against the blocks seals the opening. The two leading essen-

tials for ensilage are exclusion of moisture and strength to resist the horizontal pressure of the contents. The heat of the ferment is sufficient to exclude frost in ordinary winters in

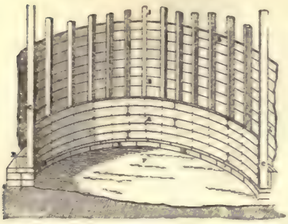


FIG. 1.

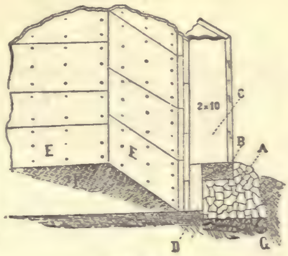


FIG. 2.

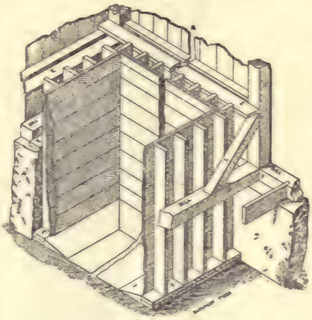


FIG. 3.

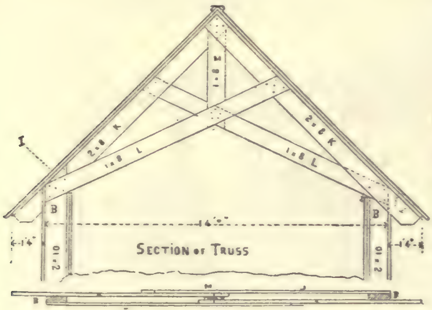


FIG. 4.

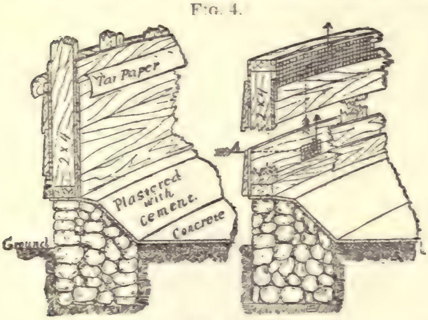


FIG. 5.

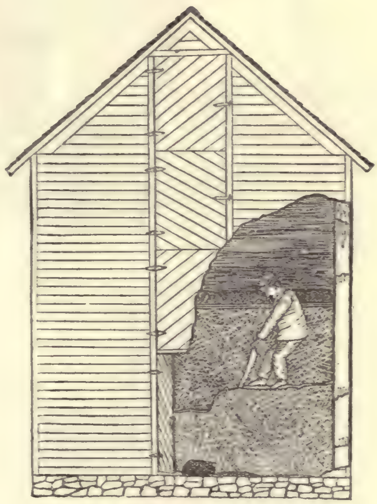


FIG. 6.—Above-ground outside silo.

FIGS. 1–6. Silo-construction.

the temperate zone. Wood is better for silo-construction than any kind of masonry. The inside surface may be advantageously coated with tar applied warm. The silo may be used repeatedly, year after year. It may comprise one or more tank-like apartments, each with its walls and floor independently tight, but preferably not more than 10 ft. square each, so that they may easily be made strong and also present a rather small top surface of ensilage to the air, as the exposed surface is subject to mildew and can not be used. The surface of the ensilage is kept covered with straw. Wherever the temperature is liable to stand for days at a time as low as zero, Fahrenheit, the silo-walls should be dead-air spaced; but where such extreme cold does not occur continuously this is unnecessary, and the pit of silage will pass through the winter unfrosted, maintaining a temperature of about 70° by its own chemical action. To avoid possible interference with the intrinsic thermal and moisture conditions to any marked extent by extrinsic influences is the main desideratum; air-tight closure is not itself the purpose, but a means to this end. The juices of the stalks are food and are to be preserved, but water from without is ruinous to ensilage so far as it gains any access, and nothing should be put in the silo while moist from rain or dew, nor should any water or moisture be allowed to penetrate. The flavor of ensilage is very acid, and animals at first eat it

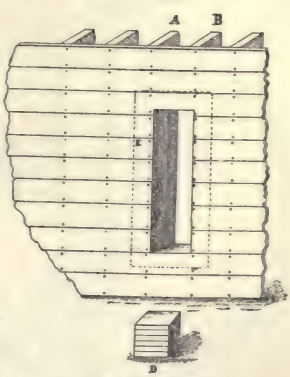


FIG. 7.—Silo-door.

under protest, but soon acquire a keen relish for and thrive on it. The flesh-and-milk-producing quality is remarkable. The available yield of land for stock-feeding purposes is vast-

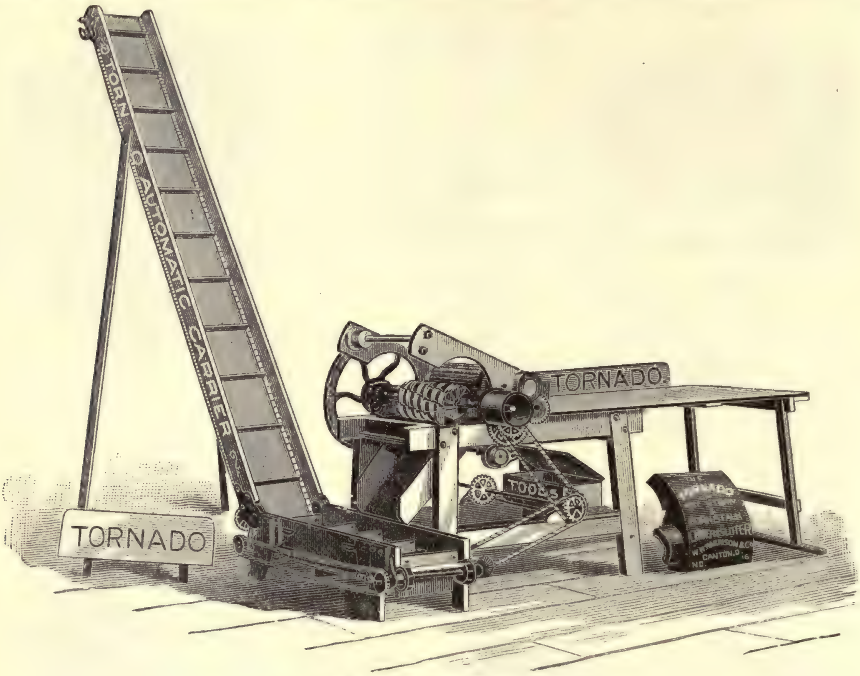


Fig. 8.—Ensilage cutter.

ly increased where it has been introduced. Indian corn, sowed or planted in drills, is the silage crop giving most profitable results. The corn or other fodder, optionally used, such

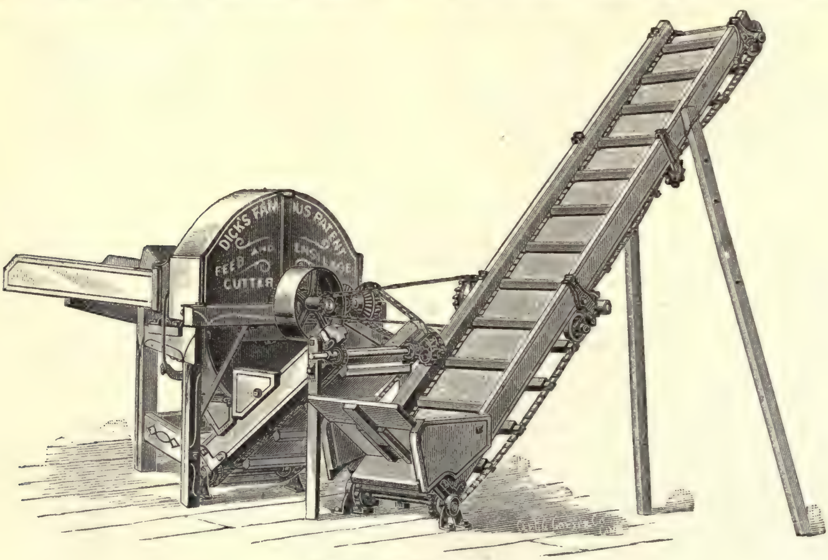


Fig. 9.—Ensilage cutter.

as root-tops, clover or other grass, is to be cut into short lengths, say 2 or 3 in., and sometimes the corn-stalks are also shredded or split as well as cut across. Taken at maturity but before they have begun to become dry, the stalks of the corn-plant, rejected by cattle when dry, are in this succulent stage preferred by them before the leaves, and in the form of ensilage the stalk-joints are the most nutritious part. Special machines are devised for the rapid and economical cutting of the silage. Figs. 8, 9, 10, and 11 represent several standard machines

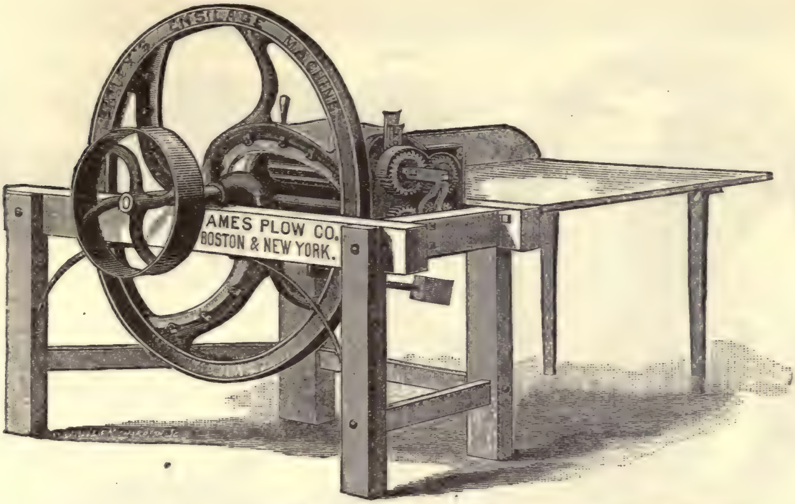


FIG. 10.—Ensilage cutter.

FIG. 11.—Ensilage cutter.

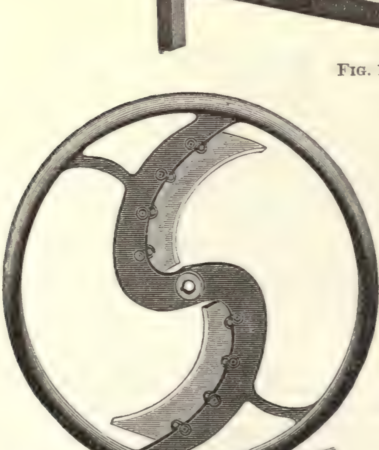


FIG. 12.—Cutter blade.

FIG. 13.—Cutter blade.

for this purpose, and clearly show the differences in construction. Figs. 12 to 17, inclusive, show various forms of blades adapted to reduce the silage material to the requisite fineness

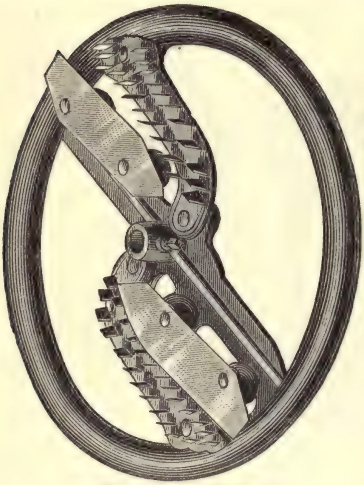


FIG. 14.—Cutter blade.

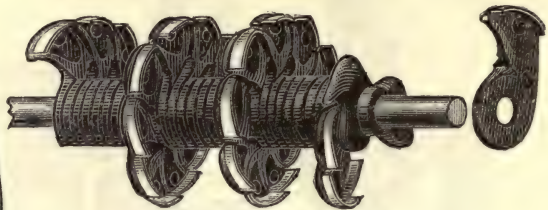


FIG. 15.—Cutter blade.

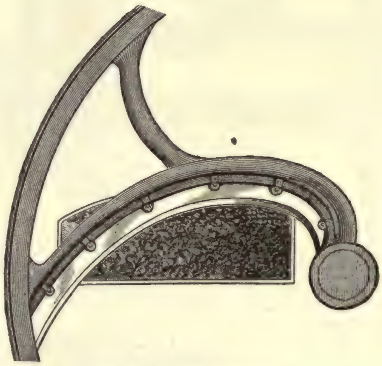


FIG. 16.—Cutter blade.

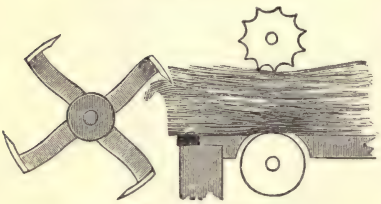


FIG. 17.—Cutter.

and condition for compact storage and active fermentation in the silo. Goffart, of France, is deemed the efficient originator of the practical application among farmers of this method of utilization of products before allowed to dry, and, so far as the richest juices are concerned go to waste. In the United States J. B. Brown, of New York, has been prime promoter, and with great success. Not only the thrift and profitableness of silage-fed cattle must be considered, but the notably increased strength and value of their manure for fertilizing. There is now an urgent demand from farmers for field machinery capable of harvesting heavy growths of sowed corn and binding the tall plants automatically in sheaves with two bands, for convenient transportation from field to the silage chopping-machine at the side of the silo.

FIG. 18.—Keystone stalk-cutter and husker.

Husking Fodder-Cutter.—The "Keystone" corn-husker and stalk-cutter (Fig. 18) is one of the silage-making machines called into being by the introduction of silos, but is to operate on crops of corn cultivated for the grain as well as the fodder. The machine delivers at one end the ears of corn, stripped of husks and silks, and at the other end the chopped silage. By husking as soon as the kernels of corn have matured, but before the plant has become withered by standing too long in the field, the value of the fodder for silage may be conserved.

This machine is mounted on four wheels, and weighs, with the two conveyers, one ton. It is operated with about the same amount of power as the large thrashers in common use. The entire corn-plants are fed in, butts first, from wagons, as they come from the field. The stalks are seized by a pair of rollers (seen at top of open Fig. 19) 3 in. thick and 20 in. long, which turn in slotted bearings, separable, but prevented by strong springs from separating far enough to admit between them any ears of corn. The upper roller is armed with projections to snap off the ear-stems; and the gravity of the ears aids to present them to the snapper-roller favorably for its work. The ears in their husks then drop upon two pairs of husking-rollers, inclined at such an angle as to clear the space near the snapping-roller and rotating at a right angle with it. The husking-rollers, which are 3 in. thick and 3 ft. long, are furnished with steel pins projecting and meshing into corresponding holes in each other. In each pair of rollers the upper faces revolve toward one another, their pins stripping off the corn-husks and silks, drawing them down through and dropping them on a carrier below, by which they are conveyed to the feed-cutter and mingled with the cut stalks for the silo. The husked ears are skidded from the rollers to a conveyer, which delivers them separately. The machine requires seven or eight attendants hauling and feeding.

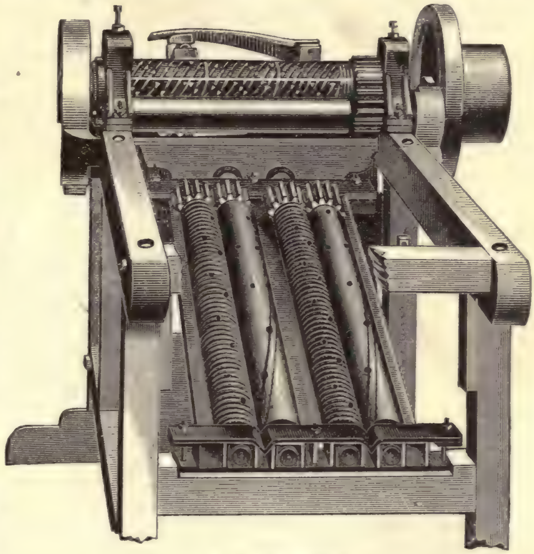


FIG. 19.—Stalk-cutter.

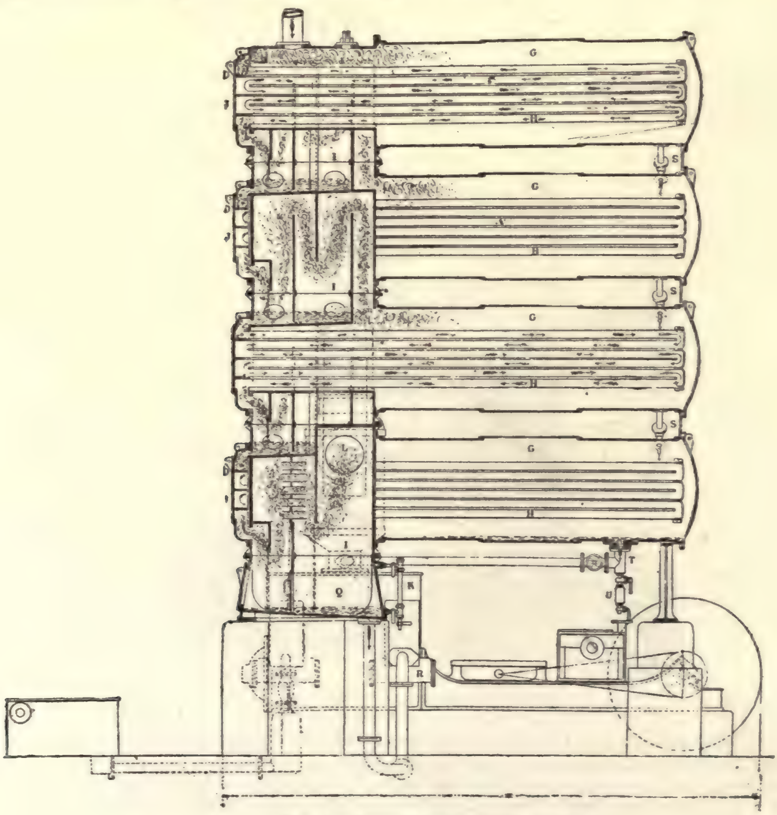


FIG. 1.—Yaryan evaporator—section.

EVAPORATORS. Up to within a recent date the most improved process for the evaporation of cane-sugar juice was that devised by Rillieux (see SUGAR-MAKING MACHINERY, vol.

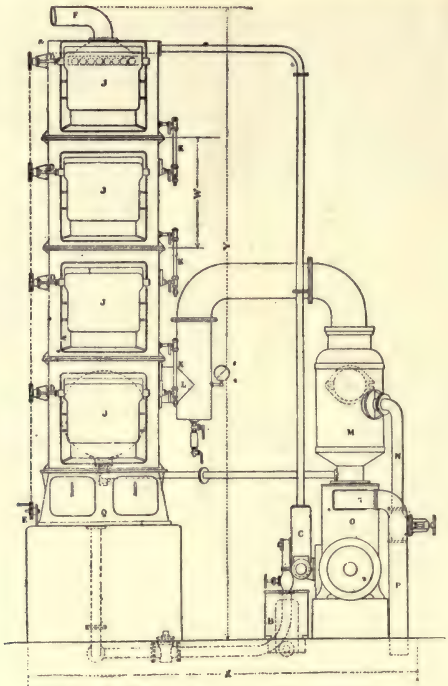


FIG. 2.—Yaryan evaporator—section.

ii of this work). The principle of Rillieux was the evaporation by multiple effect, or the use of the steam of evaporation in the first effect to further concentrate the liquid in the second operation, which is made possible by producing a vacuum in the evaporating chamber of

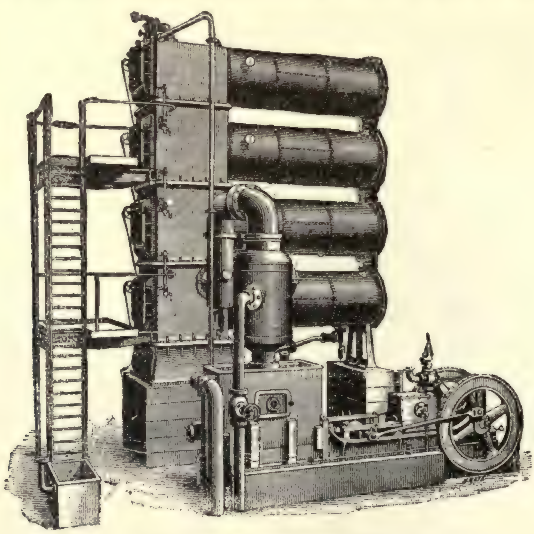


FIG. 3.—Yaryan evaporator.

the final effect, thus reducing the boiling temperature of the liquid. The steam in the surrounding chamber, or jacket, thereby condenses rapidly on the colder surface of the evaporating chamber, and thus not only imparts its latent heat to the liquid, but produces a relative vacuum in its own chamber. The defects of the Rillieux apparatus are, that a consider-

able mass of liquid lying above the heating surface, by the pressure of its own weight raises the boiling temperature of the liquid at the bottom, thus requiring more heat to perform the required work than at the surface, and also subjecting the liquid to a strong heat for an unnecessary time. This, in the case of sugar, is a fruitful source of loss, not only by inversion of the sugar, but by forming caramel.

The Yaryan Evaporator is based upon an entirely novel principle, by which the inventor avails himself of the very tendency to blow into spray which viscous liquids possess when subjected to heat, to first blow all the liquid into a spray and keep it subjected to heat in this state. He therefore constructs a horizontal tube of 60 ft. in length and 3 in. in diameter, and surrounded this with another tube, leaving an annular space of sufficient capacity to con-

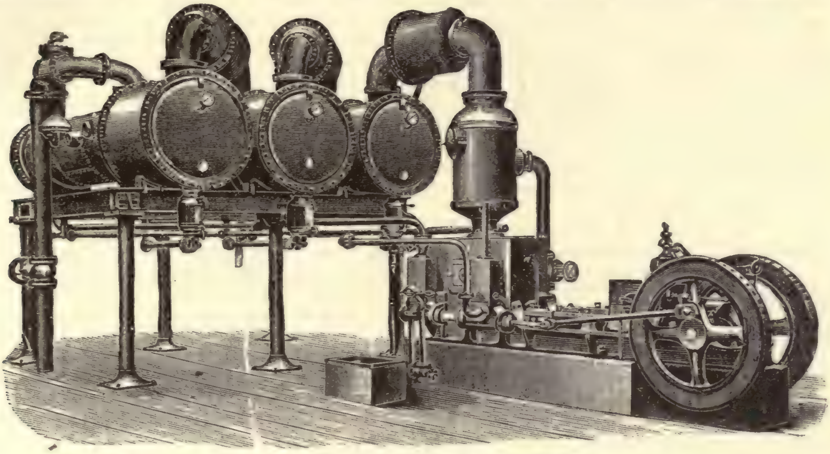


FIG. 4.—Yaryan horizontal evaporator.

tain steam for evaporation. The supply port to the inner tube was reduced to a diameter of ¼ in., and the liquid, being fed in under pressure, and steam at 5 lbs. pressure supplied to the outer tube, it was found that by the combined action of the liquid entering the tube through the constricted opening, under pressure, and the expansive force of the steam formed by its evaporation, the entire volume of the liquid is ejected from the unobstructed end of the tube in the form of mixed steam and spray. Repeated tests showed a greatly increased efficiency as the velocity of the liquid in the pipe was increased. The apparatus is adapted to the concentration of fluids, sugar solutions, sugar-cane, beet and sorghum juices, glucose, glue, gelatine, beer-worts, wine, glycerin, extracts of bark, wood, beef, coffee, licorice, alum solutions, caustic soda, waste alkali liquor from paper-mills, tank-waters from slaughter-houses, and for distilling water. Figs. 1, 2 and 3 show a section and perspective views. The process is easily followed from the sectional views (Figs. 1 and 2). The steam for the first effect enters the chamber *G*, containing the heating tubes *H*, through the inlet *F*, the liquid being fed to the return-bend heating-tubes through the valves *D*, there being a valve for each coil. Spraying and evaporation at once commence, and the mass is driven through the tubes and is discharged against the baffle-plates in the separating chamber *I*; thence the steam of the evaporation passes to the next chamber *G*, while the remaining liquid passes down into the next series of tubes through the valve *D*, and so on through the system. In the final effect a vacuum is maintained by means of the vacuum-pump and condenser. The legend accompanying the sectional view will serve for the identification of other operative parts. Fig. 3 is a perspective view of the vertical apparatus just described. Fig. 4 is a perspective view of a Yaryan evaporator of the horizontal type, differing, however, from the other only in the disposition of its parts.

Evaporators: see Engines, Marine.

Excavator: see Dredges and Excavators.

Extractor: see Separators, Steam. **Extractor, Centrifugal**: see Creamers.

Fan: see Blowers.

Feeder: see Cotton-Gin, Ore-Crushing Machines, and Thrashing-Machines.

Feed-Water Heater: see Engines, Marine, and Heaters, Feed-Water.

Felly-Borer, Felly-Rounder: see Wheel-Making Machines.

Ferro-Chrome: see Alloys.

Filing: see Grinding, Emery.

Filter-Press: see Mills, Silver.

FILTRATION. The purification of water is effected by mechanical means on a larger scale at the present time than has ever before been known. To filter a small quantity of water is not a difficult matter, but to filter millions of gallons a day involves engineering problems of magnitude. In most of the systems employed abroad sand-filters are used. The water is usually allowed to remain at rest in settling basins until the heavier matters have deposited, and then is passed to the filter-bed, through which it oozes slowly. This type of

filtration has several serious objections. It is slow, and hence unable to meet heavy drafts on it, as in the case of fire. The filter-beds acting tardily may become foul, which leads to the rapid and enormous development of bacterial life in them, and this may cause the water to become biologically less pure after passing through them than in its original state. There is no quick way of cleaning the filter-beds. In fact, there is no method of simple filtration known that is competent to handle on a commercial basis the water-supply of a large city.

The next step in the evolution of successful mechanical filtration was the addition to water of substances which react chemically with the bicarbonate of lime present in all natural waters, and form a precipitate which assists in removing the suspended matters by filtration. The addition of chemical substances to aid in clarifying water is very old. The most efficient of these substances are those which produce in the water precipitates of a gelatinous nature. The gelatinous precipitate thus formed in the water entangles and agglomerates the minute particles of suspended matter, be they mineral particles or microbes, and forms masses of sufficient size to be easily removed by the filter. Of the substances which produce in natural waters gelatinous precipitates, alum is the most readily obtained and is not surpassed in efficiency by any. The alum and the bicarbonate of lime which is in the water react on each other chemically. The alum is decomposed, and a gelatinous precipitate of aluminic hydroxide, mixed with a basic aluminic salt, is thus formed. The most searching chemical examination fails to show the slightest trace of alum in water that has been treated with the proper amount of it and then filtered.

Alum has been used for many years as a "coagulant" for water with excellent results. The treatment usually consisted in adding a certain amount of alum to the water, mixing it well and allowing the water to stand until the precipitate settled, after which the clear, supernatant water was run off to the filters. While in this way a bright water was obtained, there were still difficulties which prevented commercial success on a large scale. The subsidence plant was unwieldy, and the same difficulties existed with the filters that have been mentioned. Three obstacles remained to prevent the commercial success of filtration of water on the immense scale that large cities require. The first was the difficulties attending the cleaning of the filter-beds; the second was the time required for filtration; and the third, the great size of the filtration plant. It was reserved for us in America to solve the problem in a most ingenious way, and to devise a process that has made the cleaning of the filter-beds simple and effective; that has diminished the time of filtration to a practical minimum, and has greatly reduced the size of the apparatus.

The principles of the process now generally in vogue here are briefly as follows: On its way to the filter the water receives the addition of a minute amount of a saturated solution of the coagulant, usually alum. The amount of coagulant added varies with different waters, and even with the same water at different times of the year. Usually it amounts to about one fifth to one third of a grain to the gallon. The water having received this small dose of coagulant, so small that it seems incredible that it should produce such remarkable results, passes, without stopping to settle, directly to the filters. The most generally adopted form consists of large closed cylinders of boiler-iron filled with sand, or a mixture of sand and coke. The coagulated water passes down through these filter-beds and comes out clear and sparkling, as delicious and as tempting as a mountain spring.

Nature, however, is not content with coagulating and filtering water, but at the first opportunity sends it tumbling over some precipice, to fall against rocks and be dashed into spray until it reaches the bottom a mass of foam. In doing this Nature effects in a simple way something that has greatly perplexed engineers to imitate—i. e., to aërate water in a practical way. This aëration fills the water with myriads of minute bubbles of air. The surface of contact between the water and air is immense, owing to the enormous number of air-bubbles. In this way the water is subjected to the powerful influence of the oxygen of the air, which destroys the dissolved organic impurities, and not only kills many of the lower forms of life, but makes the life of many others hazardous by removing the organic matter on which they feed. The artificial aëration of water has been effected in the following way: A large vertical pipe many feet in length is turned back on itself so as to form a great U. Into one end of this the water is injected and falls tangling up the air with it and emerging from the other end as foam. Water so aërated takes hours to lose its air, so minute are the bubbles. The effect of this aëration is to oxidize the dissolved organic matter and greatly purify the water. To return now to the filter. After a certain duration of filtration the filter-beds become so clogged with the separated coagulum and filth that filtration becomes difficult, and if allowed to go on would soon yield a foul water from the growth in them of micro-organisms, and instead of purifying would render the water organically less pure. Long before any danger of such a catastrophe the cleaning of the filter-beds takes place. To accomplish this the current of water is reversed, and, instead of flowing down through the filter-bed, is sent with great force up through it from the bottom. The entire bed of sand is thus lifted and floats, as it were, on the ascending stream of water, yielding up all its impurities, which escape with the water through a waste-pipe. The washing of the filter is continued until the wash-water runs clear, when, by turning a few valves, the flow is reversed again and filtration is resumed. So simple are the operations of filtration and washing the beds, that one man can handle a plant filtering several millions of gallons per day.

The effect of this method of filtration on the purity of water is most remarkable. Thus the analyses of the water of the city of Atlanta, Ga., before and after filtration furnish incontestable proof of the success of the process there employed:

	Unfiltered.	Filtered.
Total solids	8·03	3·60
Oxygen absorbed	....	0·03
Albuminoid ammonia	0·16	0·03

This city has a battery of 12 filters with a capacity of nearly 4,000,000 gals. per day. Before the introduction of the filtering plant the water could not be used except for sanitary purposes. Now the filtered water is the best there is in the city.

The remarkable action of mechanical filtration in the removal of organic life in water is also marked and is of the greatest importance. It is now a well-recognized fact that many diseases are conveyed by water, and reach us in the forms of microbes, or disease-seeds. From the standpoint of the hydraulic engineer, however, so long as the microbe is a particle of insoluble matter it can be removed as easily as any other particle of solid matter—clay, for instance. The microbe and the particle of clay become alike entangled in the gelatinous coagulum, and are removed by the filter-bed. Dr. Charles V. Chapin, Superintendent of Health of Providence, R. I., has made some most interesting investigations in the water filtered by the filter plant at Long Branch, which is one of the finest yet built. In the unfiltered water he found in 1 c. c. 298 organisms. In the filtered water only two. Nature, herself, can not do better than this. (See Pure Water for our Cities, by Dr. Peter Austen, *Engineering Magazine*, No. 1, p. 95.)

The Hyatt Filtering System, invented by Isaiah Smith Hyatt, of Morristown, N. J., coagulates the impurities in the water and then filters it. The filter proper is simply a body of ordinary sea sand supported in a perforated false bottom, the whole being inclosed in a wrought-iron cylindrical vessel.

The filter is connected with the supply-pipe in such a manner that a by-pass is formed around the filter; or, in other words, it is so arranged that the filter may be disconnected without disturbing the flow of water through the main pipe. A small portion of the muddy water to be treated, not more than a fraction of 1 per cent of the total volume, goes through an attachment to the main filter, containing lumps of alum. A minute amount of alum is thus dissolved and passes into the filter, where it is mixed with the main body of water, the quantity of alum used being less than 1 grain per gal. of water. The suspended clay and other earthy matter which is of a basic nature, has the effect of precipitating the alumina of the alum, causing it to separate all through the water in the form of gelatinous flocks. These

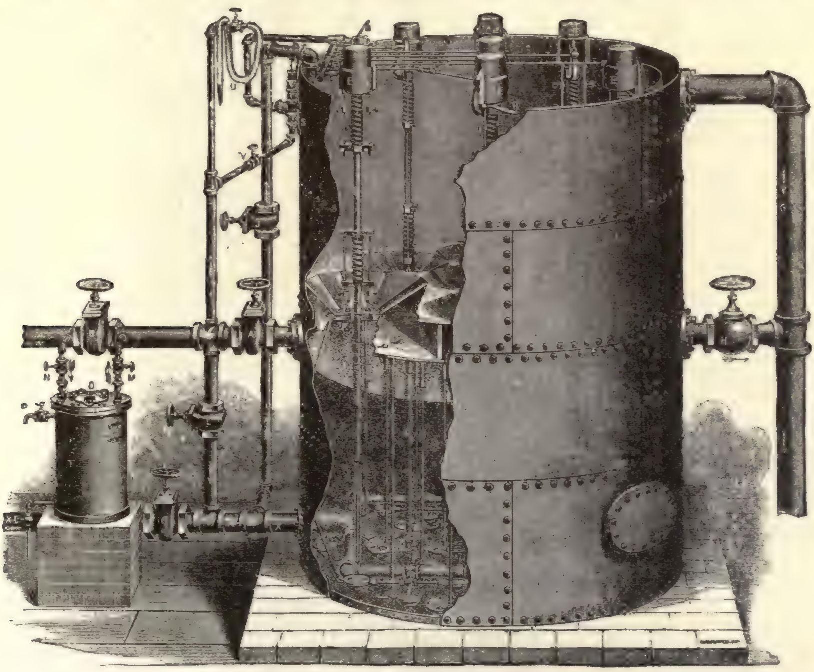


FIG. 1.—Hyatt filter.

minute particles bring together, or coagulate, the finely suspended matter, converting it into such a form that the filter will easily and completely remove it. The supply of water to this coagulator is governed by a valve regulated by a scale, each division of which corresponds to a given quantity of alum dissolved. In consequence of this reaction, the minute amount of alum employed is entirely destroyed, as such, and is removed from the solution, the fine silt which could not otherwise be removed by filtration is converted into such a form as to be

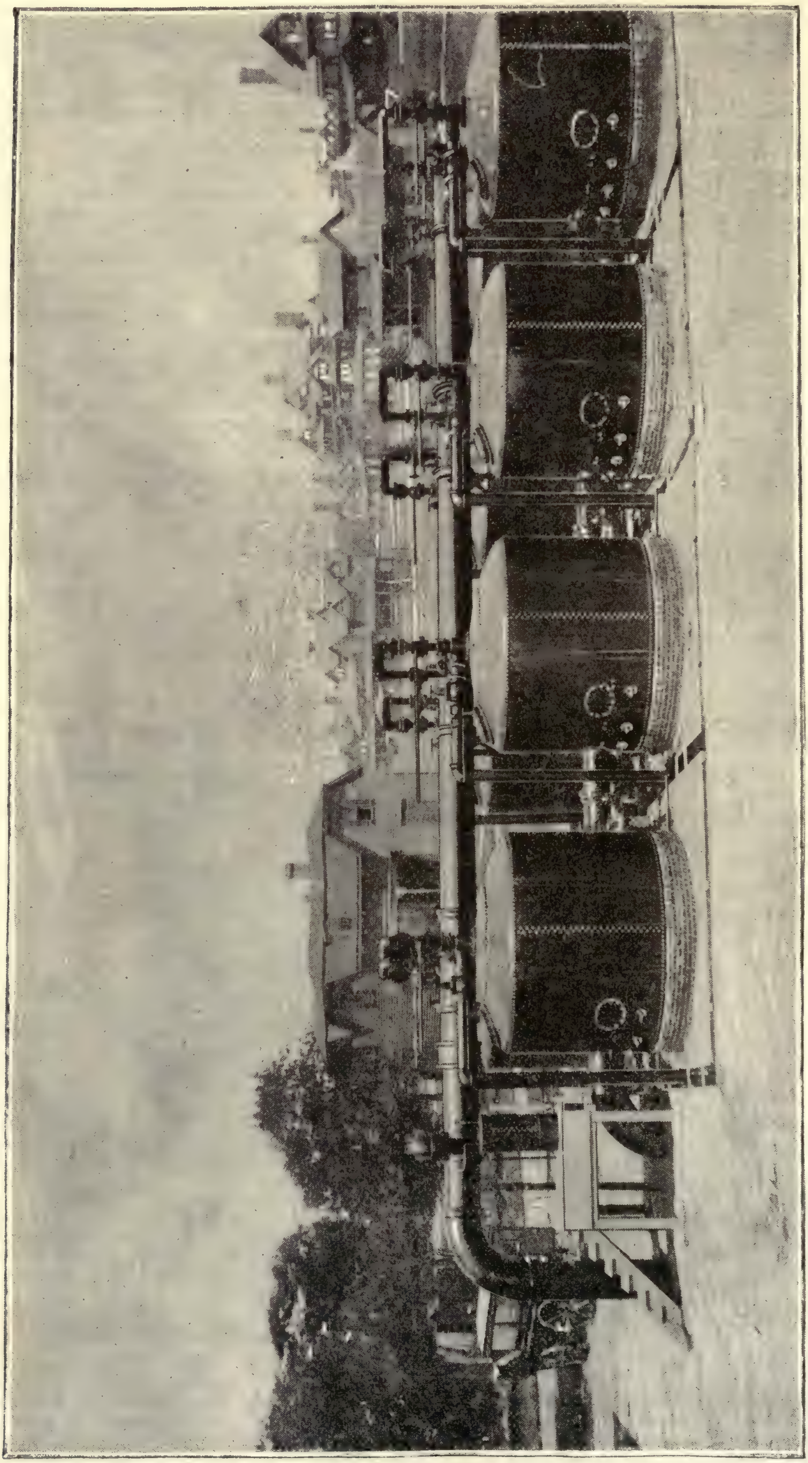


FIG. 2.—Hyatt filtering plant, Long Branch, N. J.

easily removable, and the resulting filtered water is perfectly bright and clear, no matter how dirty and muddy it may have been previously. For the purpose of cleaning the filter-bed, provision is made by which the current of water can be reversed, and the accumulation of dirt, etc., is removed through a special discharge-pipe.

Fig. 1 represents one of the largest filters of the Hyatt system. It is constructed of wrought iron and steel, with a capacity of 250 gals. per min., or 325,000 gals. per 24 hours. It is 10 ft. in diameter, 13 ft. high, and requires 392 bush. of filtering material. It is specially adapted for the requirements of large factories and industries where a great volume of water is used daily. The operation is as follows: The water enters the filter through the main inlet-pipe below the partition and above the filtering material, passing downward and out through a system of cone-valves at the bottom, which are so constructed as to prevent the filtering material from escaping, and at the same time allowing the water to flow freely to the outlet-pipe. When washing, the water passes from the inlet-pipe to the outlet-pipe, entering the filter at the bottom through the cone-valve outlet system and up through the filtering material, agitating and loosening the same and producing pressure which causes the material to be discharged into the upper tank, which is always filled with water, through the 7 discharge-pipes. The material, being heavy, settles immediately to the bottom, displacing the water which flows out through the waste-pipe, carrying with it all the arrested silt and impurities. After the material has all been discharged into the upper compartment it is allowed to settle back into the lower chamber or filter proper, displacing the water in this compartment, which flows out through the lower waste-pipe.

We illustrate in Fig. 2 the Hyatt plant at the Long Branch (N. J.) Water-Works, having a capacity of treating 2,000,000 gals. per day. This consists of 8 cisterns, each 10 ft. in diameter, and connected with a common inlet and outlet pipe: "The water having first been aërated and coagulated, flows from the main supply-pipe to and into the filters above the surface of the filter-beds, and in passing downward is relieved of all objectionable constituents, issuing through a series of wire-bound outlet screens into a common delivery-pipe, and being carried by the continuous pressure to the various consumers. At stated periods (ordinarily once each day) the arrested impurities are thrown off from the beds of filtering material into a waste-pipe leading to the sea, each filter being renovated independently while the others are performing their work of purification. During this operation the intake-pipe to the filter undergoing the operation is cut off from the main inlet, and water passes through a central vertical pipe connecting with a horizontal radial pipe at the bottom of the bed. The water issuing through this horizontal pipe saturates the bed immediately around and above it, the arrested impurities being detached and carried off by the current. While this current is flowing through the horizontal washing-pipe, the latter is gradually moved by means of a lever outside of the filter, and by the time it has passed all round the interior, agitating and scouring the mass in succession until it has arrived back to its original position, the entire filter-bed will have become cleansed, and the process of filtering is then resumed. This operation occupies usually about 10 min., but where the water treated yields an extraordinary amount of tenacious sediment a somewhat longer scouring may be necessary. The automatic aëration is accomplished before the water reaches the pumps. After leaving these it flows through the main inlet to the filters, and thence to the consumers. The plant at Atlanta, Ga., differs in construction from that at Long Branch, in the fact of having two stories or chambers, one above the other, the upper comprising the washing-chamber, separated from the lower compartment, or filter proper, by means of a partition or diaphragm, this partition being indented with funnel-shaped depressions to facilitate the return-flow by gravitation of the filtering material to the lower chamber. The unpurified water enters at a point just below the diaphragm, flows downward through the filter-bed, issues at the bottom through a series of valves all connected in one system, and is delivered into a clear-water basin, from which it is pumped by the Holly system of pumps directly to consumers. The principles of coagulation and filtering, as exemplified in this plant, are precisely the same as at Long Branch, the difference in construction consisting in the method of renovating or washing the beds. In this case the beds are washed by means of vertical pipes, through which the entire contents of the lower chamber are forced up by ordinary water-pressure and deposited in the upper or washing-chamber. The combined effect of attrition in passing through these pipes and violent contact with the water contained in the upper chamber causes a complete separation of the filtering material from the impurities, which flow with the current out through the pipe leading from the upper chamber, thence to a sewer or other outlet. This operation having been accomplished, the filtering material is permitted to return to the lower chamber by gravity through the conical apertures in the dividing partition. When thus restored to its original position all openings are closed, excepting the inlet and outlet, and the process of filtration is immediately resumed."

The report of the Board of Water Commissioners of Atlanta for the year 1890 shows that the filters used 92,390 lbs. of alum during the preceding year, equal to ·617 grain to the gal., and that the cost of filtration per million gals. was $3.83.

The Warren Filter (Fig. 3) was invented in 1885 by Mr. John E. Warren, of S. D. Warren & Co., paper manufacturers. The invention was the outcome of the necessity of a filter which would purify the large amount of water used in the Cumberland Mills of the above firm, this being now the largest mechanical filter-plant in existence, having a daily capacity of 12,000,000 gals. The chief merit claimed for this filter is the mechanical rake or agitator. By its use the sand composing the filter-bed is thoroughly scoured, and the filtered water is only used to rinse off the dirt thus loosened. As a result of this method of procedure, the filter can be

rapidly and thoroughly cleaned with the minimum consumption of water. Experiments also pointed to the fact that insufficient time was usually allowed for the reaction of the alum or other coagulant used in the water; hence, in the Warren system, the coagulant, in the form of a solution of definite strength, is pumped into the water as it passes to a settling-basin or tank so proportioned in size as to allow each particle of water to remain in contact with the coagulant the length of time found necessary for the chemical reaction. In this way it is claimed that a greater economy of the coagulant is obtained, and the possibility of its passing into the filtrate is removed—a point of much value where the water is used for domestic purposes. The filter, by combining coagulation, sedimentation, and filtration, by the use of an open filter-bed so arranged as to be quickly and mechanically freed from the intercepted matter, and by the use of a light pressure never exceeding $\frac{6}{10}$ lb. per sq. in., is intended to unite all desirable features with a comparatively inexpensive form of construction.

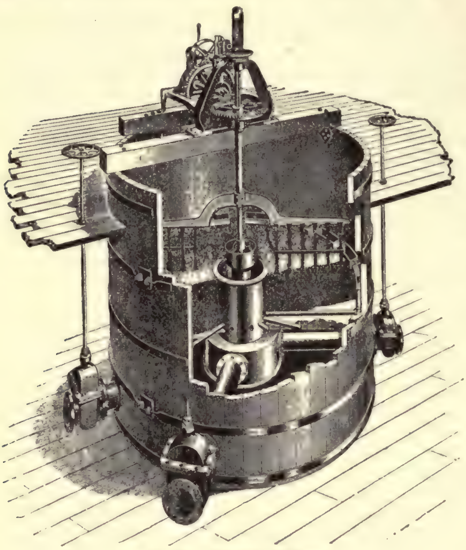


FIG. 3.—Warren filter.

From Fig. 3, which clearly exhibits the internal mechanism, the operation of this filter will be understood.

During filtration, the unfiltered water, entering through the valve, passes up into the filter-tank, thence downward through the filter-bed, supported by the perforated plate, and through the filtered water-main, by which it is carried to the mill. When it becomes necessary to cleanse the filter-bed the valves are adjusted to allow the water in the tank to pass into the sewer. When the water in the tank has been drawn off, the agitator is set in motion, and driven down into the bed by means of the screw shown, while at the same time a slight amount of filtered water is allowed to flow back up through the bed, in order to rinse away the dirt which has been loosened by the scouring action of the revolving agitator. When the flow of water up through the bed becomes clear the agitator is raised, the waste-gate closed, and by the opening of the valves filtration is resumed.

The National Filter.—This filter, manufactured by the National Water-Purifying Co. of New York, is represented in section in Fig. 4. The filter proper is about two thirds filled with indestructible fine quartz sea sand. In the top of the filter-case is shown a device for supplying a minute quantity of chemical solution to the water when it is very roily or turbid or impregnated with sewage, the effect of the chemical being to precipitate the impurities in solution and suspension, while the chemical itself is retained with the impurities it precipitates upon the top of the filtering material, so that no trace of it (even by analysis) appears in the filtered water. In the bottom of the filter are shown the brass tubular strainers for preventing the sand passing out with the filtered water. These strainers

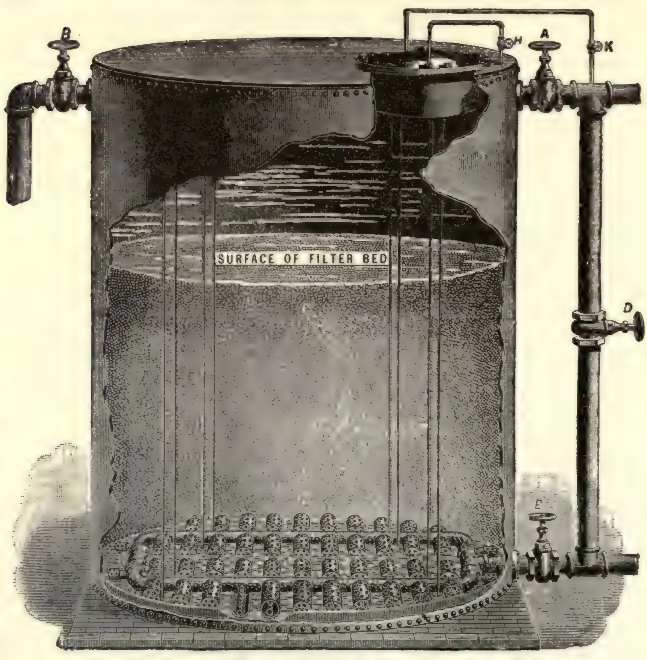


FIG. 4.—National filter.

are filled with gravel, and are half imbedded in cement—up to the line of perforation—which prevents any filth and disease-germs from settling below them, where they could not be reached and dislodged by the reverse current when washing the filter. They are also so proportioned and constructed that in washing the filter they insure a complete reverse-current in every part of the bed, which does away with the necessity of any mechanical appliance for stirring the bed when washing. The water to be purified is admitted under pressure to the filter at *A* above the sand filter-bed, and where, if necessary, it is mixed with a minute quantity of chemical solution as above described; it then passes down through the sand, brass strainers, and outlet-pipe *E* back into the service-pipe, leaving the commingled impurities and chemical (if used) on the surface of the filtering material at the top of the filter. Once a day the water should be shut off from the inlet, above the filtering material, and be allowed to enter the filter in the reverse direction, from the bottom at *E*. It will then pass up through the filtering material, which it thoroughly loosens and scours, carrying the commingled impurities and chemical on the surface of the filter-bed off through the waste outlet *B*, which connects with the sewer. This operation only takes 10 min. time, when the water is again admitted at the inlet at top of the filter as before, and filtering recommences. The waste *B* (at some point close to the filter) should be left exposed by means of a trough or funnel, so that the condition of waste washing-water will show when the filter-bed has been thoroughly cleansed. The National filtering system is in use in Chattanooga, Tenn., 6,000,000 gals. daily capacity; Terre Haute, Ind., 3,000,000 gals. daily capacity; and in various other cities of the United States.

Small Filters and Filters for Special Purposes.—The Jewett filter, made by the John C. Jewett Manufacturing Co., of Buffalo, embodies a cup containing sponge and a vessel containing gravel, through both of which the water passes into a settling receptacle. After overflowing the latter it proceeds through the filtering-bed proper, which consists of layers of gravel, sand, and decarbonized charcoal.

A Filter-Press for Porcelain Clay, devised by M. P. Faure, of Limoges, France, and described in *Engineering*, January 17, 1890, possesses many novel features. The clay and water are mixed to the consistence of cream, and are pumped into the filter-press. The mixed clay and water are not allowed to come in contact with the plunger of the pump, an elastic diaphragm being interposed, the vibrating movement of which forces the material into the press; the pump-cylinder has two plungers, one working within the other, and so arranged that the smaller one can be put in operation when it is desired to increase the pressure in the filter-press. The last-named apparatus has a cast-iron frame, on the longitudinal bars of which are hung a series of cast-iron rings covered with iron gauze; between the frames thus formed canvas bags are placed, so arranged that the liquid which is delivered by the pump to a central opening in one end of the press, receives it, and allows the water to pass freely. The series of frames and bags are held together by the end screw, and the pressure that can be exerted within the filter by the pump varies from 120 lbs. to 150 lbs. per sq. in.; the clay freed from the water that held it remains in the form of compressed cakes in the bags, and about 500 lbs. of clay ready for the edge-runners can be turned out from one of these presses per hour.

FIRE APPLIANCES. All methods for the prevention of fires fall so short of the ideal of immunity that there is a necessity for fire-apparatus. The principle of defense of a manufactory against fire is that of self-protection by making the installation and management of the fire-apparatus of such a grade as to be able to cope with the progress of any fire which can possibly occur. The merits of fire organizations have already been considered as essential to the service of fire-apparatus.

Buckets of water are the most effectual fire-apparatus. They should be kept full and distributed in liberal profusion in the various rooms of a mill, being placed on shelves or hung on hooks, as circumstances may require. In order to assist in keeping them for fire purposes only they should be unlike other pails used about the premises, and in some instances each pail and the wall or column behind its position bears the same number. It is a mistake to keep fire-pails in dry-rooms, as the water in the pails evaporates rapidly, and also in so doing interferes with the drying processes. The pails should be placed in some convenient situation near to the dry-room, where they will not oppose the drying process, and will also be more accessible in case of fire than when hung inside of a dry-room. In unheated buildings the contents of fire-pails can be prevented from freezing in winter by adding chloride of magnesium to the water. Galvanized-iron pails are better than wood pails, and indurated fiber makes a very satisfactory pail, especially in places around bleacheries, chemical-pulp, or paper mills, where corrosive fumes rapidly injure metal pails. There are various expedients to insure the full condition of fire-pails, such as various floats or electrical contrivances, or sealing over the top of the pail some thin sheet of impervious material; but the fact is that there is no fire-apparatus so simple and effective as a full pail of water in good hands. All automatic devices are not above contingencies, and they lead to lowering the standard of personal espionage, which is the controlling principle in the administration of affairs. Generally there is also need of casks of water to furnish a further supply to the fire-pails. Garden-hose attached to a supply of water often constitutes a very useful portion of the fire-apparatus. Any cocks in the nozzles should be fixed in an open position by striking a heavy blow on the handle of the plug-cock commonly used in such fittings. Automatic sprinklers have proved to be a most valuable form of fire-apparatus, operating with great efficiency at fires where their action was unaided by other fire-apparatus, particularly at night. In mill-fires the average loss for an experience of twelve years shows that in those fires where automatic sprink-

lers formed a part of the apparatus operating upon the fire the average loss amounted to only one nineteenth of the average of all other losses. If the difference between these two averages represents the amount saved by the operation of automatic sprinklers, then the total damage from the number of fires in places in which automatic sprinklers are accredited as forming a portion of the apparatus has been reduced $6,225,000 by the operation of this valuable device. Although there have been numerous patents granted to inventors of automatic sprinklers since the early part of the present century, yet their practical use and introduction has been subsequent to the invention of the sealed automatic sprinkler by Henry S. Parmelee, of New Haven, Conn., about twelve years ago. This device being the first, and for many years the only automatic sprinkler manufactured and sold, and actually performing service over accidental fires, to him belongs the distinction of being the pioneer and practically the originator of the vast work done by automatic sprinklers in reducing destruction of property by fire. Although nearly or quite 200,000 Parmelee automatic sprinklers have been installed, their manufacture has been supplanted by other forms, and the total number of automatic sprinklers in position at the present time must be about 2,000,000.

In an automatic-sprinkler system the sprinkler-heads are attached to tees in pipes against the ceiling; the arrangement being such that there shall be at least a sprinkler to every 100 ft. of floor, some places requiring a still larger number of sprinklers. There should be two sources of water-supply, with check-valves in the pipes leading into the sprinkler system, giving it the benefit of the greater pressure without the intervention of any personal act. If one of these supplies is furnished by an elevated tank, the minimum head from the bottom of the tank to the highest sprinkler should be not less than 12 ft. The inability to withstand freezing temperatures is a defect in automatic-sprinkler systems which has not been fully remedied by invention. There are many so-called dry-pipe systems, in which the water is kept from the system until fire occurs, when the heat which releases the sprinkler is presumed to actuate devices which open the main valves, admitting water to the system. Such apparatus is always complicated. These systems have sometimes proved to be inoperative at fires, and have been frequently discovered to be out of order when examined. The attempts at making a solution of low-freezing point, which should be non-combustible, and under the conditions of its use should also be non-corrosive, do not appear to have been successful. Water is sometimes removed from automatic-sprinkler systems during cold weather by pumping in air to a pressure sufficient to displace the water. This method demands a great deal of attention; and in case of a fire it requires even longer to discharge the compressed air from the pipes and throw water on the fire than would be the case with the usual dry-pipe system.

The only resource for automatic sprinklers in rooms liable to temperatures below the freezing-point appears to be to shut the supply-valve and slowly draw the water from the pipes late in the autumn and to admit the water in the spring. The valves should be in a place accessible at time of fire, and all persons liable to have any duties in the matter should be made acquainted with the necessity of opening such valves in time of fire. The discharge of automatic brass sprinklers, including the resistance of the pipe-fittings may be represented by $Q = 6 \sqrt{p}$, in which Q equals the discharge in cu. ft. per min., and p the pressure in lbs. per sq. in.

The following standard of sizes for pipes for automatic-sprinkler installations is based upon the principle of using the nearest commercial sizes permitting a uniform frictional loss through the system:

Number of sprinklers.	Diameter of pipe.	Number of sprinklers.	Diameter of pipe.
115	4 inches.	10	½ inch.
78	3½ "	6	1¼ "
48	3 "	3	1 "
28	2½ "	1	¾ "
18	2 "		

When automatic sprinklers were first introduced there were many apprehensions that leakage and also excessive water discharged upon small fires would be sources of damage. In England this opinion found expression in increased insurance rates in buildings where automatic sprinklers were installed. Many automatic sprinklers have been made in such a manner as to impose unusual stress upon the fusible solder, which is a weak alloy, possessing but little resilience, and therefore ill-adapted to withstand the forces due to water-pressure. water-hammer, and what is sometimes greater than either, the initial tension in setting up the sprinkler to make it tight. It is not surprising that such sprinklers break or leak; but among the score or more automatic sprinklers on sale it is easy to select several varieties, any one of which would impose but little risk of leakage from water-pressure. The logic of figures shows that this liability to damage is merely nominal in the case of well-constructed sprinklers. An association of underwriters who have given careful attention to the subject obtained the facts that out of 514,071 automatic sprinklers which had been in actual service on the average for five years, under a water-pressure reaching in some instances 180 lbs. to the sq. in., but averaging 69 lbs. to the sq. in., there had been only 58 instances of sprinklers leaking from water-pressure, and 317 instances of leakage from other causes than fire, generally by accidents to the machinery or by carelessness of the employés, the average damage from all these causes being $2.56 per plant per annum. Although automatic sprinklers have proved to be so reliable and effective, yet, in order to provide for all possible contingencies, their introduction should not displace other forms of fire-apparatus, particularly stand-pipes in the stair-

way-towers with hydrants at each story. The hose at these hydrants should be festooned on a row of pins, or doubled on some of the reels made especially for such purposes. Stand-pipes are not recommended to be placed in rooms or on fire-escapes; and inside hydrants should not be attached to the vertical pipes supplying automatic sprinklers. One pound of burning wood produces sufficient heat to evaporate 6½ lbs. of water, and owing to the waste, a much larger proportion of water to fuel is necessary to quench a fire.

Fire-pumps are generally too small for the work required of them, 500 gals. per min. being the minimum capacity recommended. For a five-story mill there should be an allowance of 250 gals. per min. for an effective fire-stream through a 1⅛-in. nozzle, and for lower buildings the estimate should rarely be less than 200 gals. for each stream. Contrary to the general assumption, a ring nozzle is not so efficient as a smooth nozzle, the relative amount of discharge of ring and smooth nozzles of the same diameter being as three is to four. For stand-pipes ¾-in. nozzles are recommended, but for yard-hydrant service the diameter should never be less than 1 in., and 1⅛ in. generally fulfills the conditions of the best service. It is important that the couplings on the hose and hydrants should fit those of the public fire department. The best diameter of hose is 2½ in., the loss by friction under equal deliveries of water being only one third in a 2½-in. hose of what it is in a hose 2 in. in diameter. Fire-pumps should be equipped with a relief-valve and also a pressure-gauge, and placed where they will be accessible under all circumstances, and so connected that they can be started at least once a week.

The best location for fire-pumps is a matter differing with the conditions of each mill, but they should be situated as near to the source of supply as practicable, with full-size suction-pipe, easy of inspection and not containing any avoidable bends. In a steam-mill it is sometimes preferable to draft the water from a point below where the water of condensation is discharged into the stream, as there is less freezing there. In mills driven by water-wheels it is a convenience in time of repairs for steam fire-pumps to draft water from the wheel-pit. Rotary fire-pumps should have a short draft, but not placed below the level of the supply. Water-mains about a mill-yard should be of ample capacity not to cause an excessive loss by friction, their diameter being based upon a limit of velocity of 10 ft. per sec. for the maximum delivery. The yard hydrants should be placed at a distance of 50 ft. from buildings, and covered with a house which should also contain hose, nozzles, axes, bars, and spanners. Hydrant-houses are made in a great variety of forms, but it is important that the doors should be high enough to avoid ice, or that the house should be placed upon slight mounds. An economical hydrant-house may be built 6 ft. square with two adjacent sides hung on hinges, so that the doors can be swung around to the other side and be held by catches. The pins on which the hose is hung should be 2 in. in diameter, and placed diagonally and staggered in two rows. If there is no hose-cart, the reserve hose can be placed on shelves. Stop-valves in the mains should be covered by boxes 4 ft. in height, and the direction of opening clearly marked on the hand-wheel of the gate. (The foregoing is taken from Methods of Reducing Fire Loss, by Mr. C. J. H. Woodbury, *Trans. A. S. M. E.*, vol. ii, p. 271.)

I. Fire Trucks and Ladders.—Various devices have been constructed for elevating ladders against a burning building, so as to allow both of escape of inmates and ready access of the firemen.

The Hayes Extension Ladder-Truck, manufactured by the La France Fire-Engine Co., of Elmira, N. Y., is illustrated in Figs. 1 and 2. Fig. 1 shows the ladder during elevation, and Fig. 2 in upright position. The ladder is telescopic, giving a total height of from 60 to 85 ft. from the ground, made in two slides, and worked by an endless chain and winch

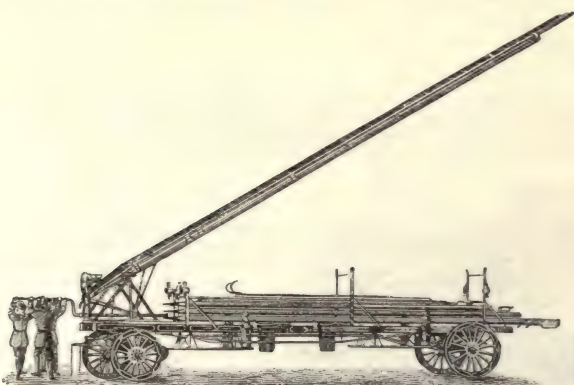


Fig. 1.—Hayes extension ladder-truck.

Fig. 2.—Hayes extension ladder-truck.

attached to the truck. The lower portion is hung on trunnions supported on an A-frame, which stands on a turn-table which is attached to the main frame of the truck. From the under side of the ladder is hung a pair of arms carrying a nut which is hung on trunnions,

and through which passes a screw, one end of which is held in a swivel fastened to the revolving portion of the turn-table on the front end. The back end extends under the ladder, and the front end is squared for a crank, so that by turning the screw the ladder is raised to the required elevation; then the turn-table is swung around, and, if necessary, the extension of the ladder is run out. The ladder is lowered over against the building, as may be desired. As the ladders are being raised to a vertical position, they can, by means of the turntable, be turned in any direction required, and by simply manipulating the turn-table, screw, and extension-cranks the top of the ladder can be readily directed to any desired point within reach. The truck can also be moved from point to point without letting down the ladders, thus enabling the firemen to reach every point of a burning building. With a little practice this can be done with precision and great rapidity. In less than one minute the ladders can be fully extended and placed against a building ready for service. In raising the ladders, electrical wires can often be avoided, but if encountered a man can ascend the ladder at any angle and cut them. The ladders being raised by means of a powerful screw, the action is certain and perfectly safe. Only 8 or 10 ft. width of roadway is required for the truck, and it can be operated as well in a narrow alley as in a wide street. But five or six men are required to work it. A rope is provided for handling the hose. To one end is attached a hook. The rope is passed over the ladders through a sheave attached to the top end of the extension ladder; thence it passes down under the ladders and through a snatch-block provided on the frame. The end of this rope is left slack when the ladders are being raised. When they are in position the hose is hooked on and readily raised to the top, where it can be securely strapped to the ladders. The rope can also be made useful in saving lives and property.

As an aërial ladder this truck can be used with safety to the height of the main ladder, which is about 50 ft. in the first class, and 40 ft. in the second class, from the ground. The ladder is placed in a nearly vertical position, and two lines of hose carried to the top may be directed by the pipe-men in any direction, carrying a full fire-pressure stream. The frame, made extra strong and supported by truss-rods, is mounted on platform-spring over front axle and two full elliptic springs over hind axle. The hind-gear is controlled by a cog-gear operated with a wheel in the hands of a tillerman, by means of which the truck can be guided around short corners and through narrow alleys.

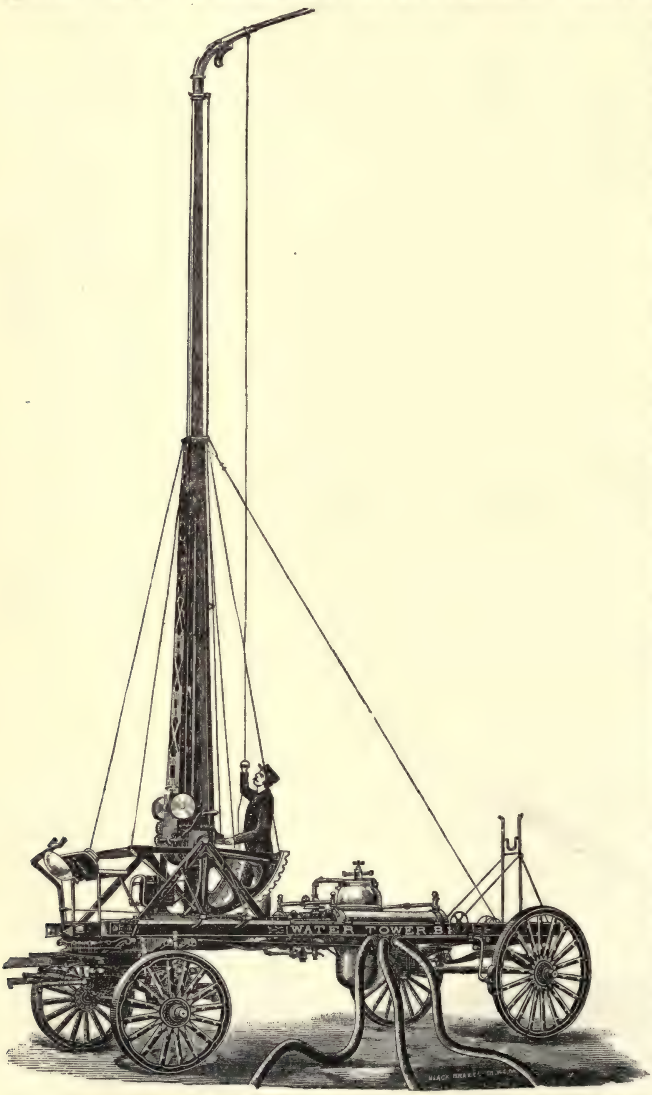


Fig. 3.—Hales water-tower.

WATER-TOWERS are pipes mounted on trucks, which can be elevated when in proximity to a burning building so as to throw powerful streams of water from their upper ends directly upon the roof or into the windows.

The Hales Water-Tower, represented in Fig. 3, consists of a strong oak framework

mounted on wheels and carrying an iron frame with an extending telescopic tube, through which passes the hose conducting the water from the supply to and through the pipe at the top end. The motive or lifting power is furnished by a chemical tank.

The tower proper is hung on and supported by a steel shaft, which rests on two wrought-iron frames. It is constructed of angle steel, with sheet-steel sides, riveted together with hot rivets, and is 22 ft. long, 2 ft. 6 in. by 15 in. at the bottom, and about 8 in. square at the top. It is raised by the quadrants and guy-rods. In the tower, and telescoping it, is a steel 6-in. tube 28 ft. long, strengthened by four steel T-ribs which may be extended by means of a $\frac{5}{8}$ phosphor-bronze cable attached to two spools and a gear at the base of the tower, passing over brass sheaves at the top and running down into the tower around the bottom of the tube. On the end of the tube is a small turn-table revolved by gearing. Attached to this are two wrought-iron arms, supporting the pipe, with the three sizes of nozzles—$1\frac{5}{8}$ in., 2 in., and $2\frac{1}{4}$ in. The turn-table is operated by a cast-steel rod running to the base of the tower, turned by a small wheel, and this directs the stream in any direction desired. The tower rests on an iron saddle or framework. The raising of the tower is controlled by a wire cable and snubbing-block in connection with the power used by the tank. On both sides, if desired, are two 3-way Siamese connections, receiving the water and conducting it into a 60-ft. length of $3\frac{1}{2}$ hose, passing up through the tube into and through the pipe. There are four sizes of towers made—30, 45, 55, and 60 ft. high from the ground to the top of the pipe when extended.

The benefits claimed for the tower are as follows: A building being heavily charged with smoke, it is impossible for firemen to gain an entrance to the bottom or upper stories. By placing the tower in the street opposite the building, one sweep of the 2-in. stream is sufficient to break all the glass from the windows, and give the building such ventilation as will enable the firemen to enter and quickly locate, and often extinguish, the fire in its incipiency. It is also very useful in lumber-yard fires, or in frame districts, and will wet an area of 400 ft. in diameter at one setting. It requires but two men to operate it.

Fire-Harness.—A form of swinging harness employed to expedite the securing of the horses to fire-engines is represented in Fig. 4. The harness is usually suspended and so disposed that when the horse, after being automatically released from his stall, places himself under it,

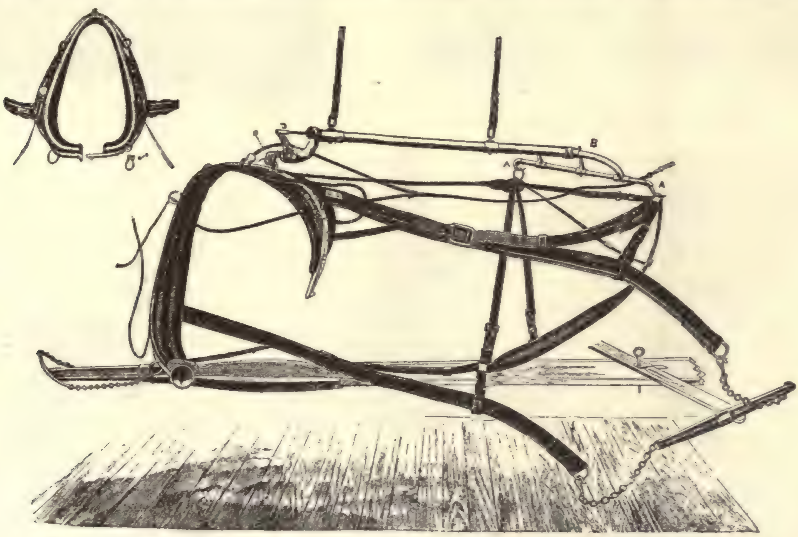


Fig. 4.—Fire-harness suspended.

it may be immediately lowered into position upon the animal and fastened in the quickest possible manner. In the stall swinging harness the suspending device consists of a hollow bar, through which passes a rod. This rod connects with the lever *B*, Fig. 4, on the rock-shaft, which engages with the top and outside rings of the breeching. The rod is pivoted to the arm *D*. The rock-shaft has hooks *A*, which are held in upward position by the weight of the collar when attached to arm *D*. By clasping the harness and collar combination around the horse's neck, the hook which is permanently attached to the harness automatically releases the lever *D*. The rock-shaft then rotates and the hooks *A* turn downward, the breeching drops on the horse, and the whole suspending device runs up to the ceiling.

Fire-Hose Appliances.—Under this heading are grouped the various appliances used in connection with hose. These are: I. Nozzles and Play-Pipes; II. Couplings; III. Connections; IV. Hose-repairing Devices.

I. Nozzles and Play-Pipes.—Figs. 5 and 6 represent a novel form of flexible play-pipe made of rubber-lined cotton, wound on the outside with brass spring-wire. At *A* is shown a

simple form of nozzle, which is opened or closed by the movement of the swinging pail, as indicated by the dotted lines. Fig. 7 shows—

The Shaw Controlling and Shut-off Nozzle (in section), by means of which a stream can be reduced to any size or shut off at will. A conical plug, operated by an exterior hand-wheel, is inserted more or less into the throat of the pipe.

The Clemens Controlling and Spray-Nozzle (Fig. 8) is somewhat similarly constructed, the conical plug being moved into and out of the constricted throat by means of an exterior nut.

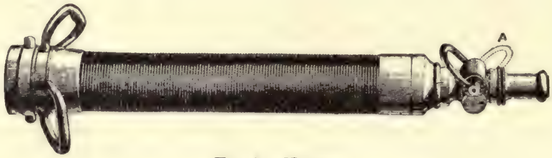


Fig. 5.—Nozzle.

Fig. 6.—Nozzle.

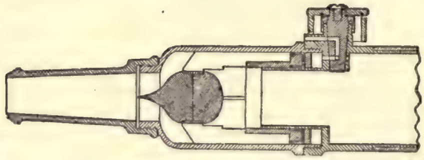


Fig. 7.—Shaw shut-off nozzle.

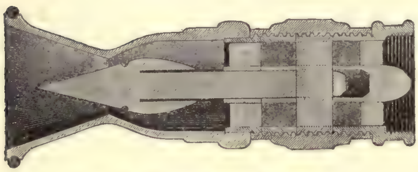


Fig. 8.—Clemens spray nozzle.

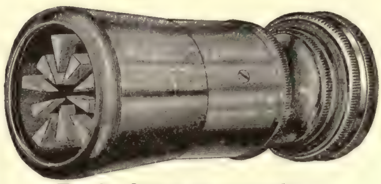


Fig. 9.—Oyston spray-nozzle.

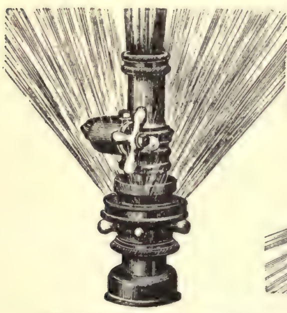


Fig. 10.—Prunty nozzle.

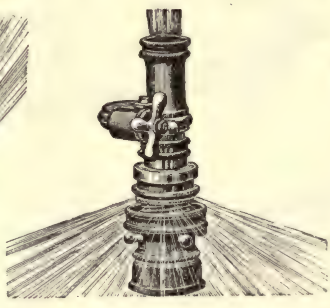


Fig. 11.—Prunty nozzle.

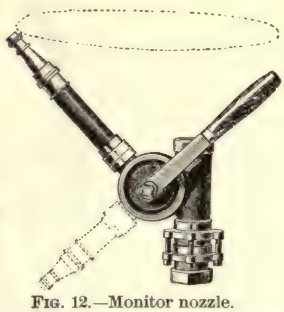


Fig. 12.—Monitor nozzle.

The Oyston Spray-Nozzle (Fig. 9) enables the pipe-men to approach and enter a burning building, and with it the excessive use of water and unnecessary damage to goods may be avoided. It consists substantially of a common nozzle having a number of small levers pivoted around it near the outer end. These levers extend about 2 in. beyond the end of the nozzle, and are inclosed in a neat cup or guard, completely protecting them from injury. The ends of these levers are connected with a collar in such a manner that, when the collar is revolved one eighth of a revolution to the right, the wedge-shaped parts of half the levers are projected into the stream, dividing it up into a number of triangular streams. By turning the collar $\frac{1}{8}$ in. farther, the remaining four levers are projected into the stream, dividing it up into double the number of streams. These streams, after leaving the nozzle a few feet, become a dense mass of flying spray.

Spray-nozzles are exceedingly effective in fighting smoky fires, the spray driving the smoke from in front of the fireman, and also keeping up a current of cool air, while the solid stream directed from the same nozzle is projected into the burning mass. The circular sheet of spray may be from 80 to 100 ft. in diameter. In Figs. 10 and 11 is represented—

The Prunty Combination Nozzle.—This is provided with an adjustable ring, which, encircling the spray openings, directs the sheet of spray either forward, as shown in Fig. 10, or backward, as in Fig. 11, the solid stream being simultaneously projected from the nozzle proper.

The Monitor Nozzle, manufactured by Messrs. A. J. Morse & Son, of Boston, Mass. (Fig. 12), is intended to be attached to stand-pipes, hydrants, or at any place where there is a water-supply, and whence it is desired to have an effective stream instantly available in case of emergency. It consists of a chamber which rotates upon its base, provided with a hose-pipe, which pipe, by means of a hand-lever, may be elevated or depressed at any angle. The nozzle has practically, therefore, a universal motion, which allows it to be directed to any point. The change of direction can be made with very little exertion, even with a 2-in. stream operated under 125 lbs. pressure or more, and carrying about 1,000 gals. of water per min. One man can easily control it, and not the least of its advantages is that, when a building is provided with several such nozzles, a single watchman can start an effective stream upon a fire, leave it in full operation while he hastens to the next nozzle and starts another stream, so that even before an alarm is given the work of one man may be of the greatest value.

Fig. 13.—Perfection nozzle.

The Perfection Holder and Nozzle (Fig. 13), manufactured by Messrs. Samuel Eastman & Co., of East Concord, N. H., is an effective device for handling fire-streams without the use of discharge-pipes. By its aid one person may direct two, three, or four nozzles all at the same time from different lines of hose with over 100 lbs. water-pressure at each nozzle. It consists of a holder for the hose-section and a short nozzle easily attached thereto. The device is held by the user, as shown in the figure.

In the Hale vacuum-nozzle, represented in Fig. 14, the air enters through side openings *A*, producing a contracted stream which it is claimed can be projected over unusually great distances.

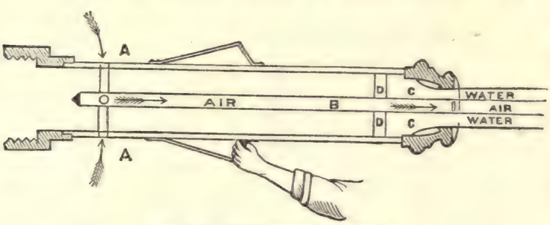


Fig. 14.—Hale vacuum nozzle.

II. Couplings.—The principal advantage claimed for the Silsby coupling (Fig. 15) is that, it furnishes a clear and unobstructed passage-way for the water the full size of the hose. It will be noticed that the inside of the shank of the coupling is beaded, and that the internal metal ring is expanded in slight corrugations, thus attaching the coupling to the hose securely. By the same means the end of the hose is protected from the water, thereby preventing mildew and rot.

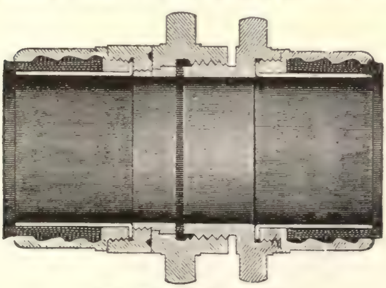


Fig. 15.—Silsby coupling.

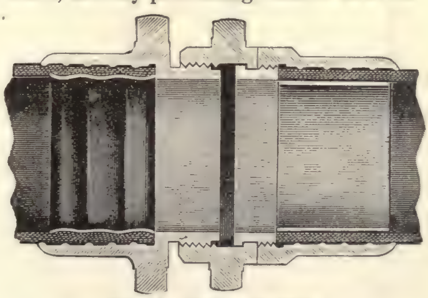


Fig. 16.—Morse coupling.

The construction of the Morse coupling will readily be understood from Fig. 16. The hose here is held between a flanged inner ring and an outer ring having its inner surface corrugated, the inner ring being expanded.

III. Connections.—To successfully cope with a large fire a powerful stream is indispensable; this can be produced by concentrating, through use of a "Siamese" (Fig. 17), the streams

Fig. 17.—"Siamese" coupling.

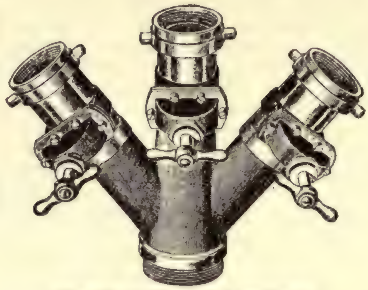


Fig. 18.—"Siamese" coupling.

of three or more steamers into one of suitable size and force, which pours such volumes of water into the fire that it is actually drowned out. A peculiar advantage of this concentrated stream is, that it has sufficient force and quantity to reach the fire itself and not turn to steam in the intense heat, thus destroying its efficiency, as is the case with an ordinary single stream in a hot fire.

A distinguishing feature of the "Siamese," made by Messrs. A. J. Morse & Son, of Boston, Mass., and represented in Fig. 17, is that the pipe is attached directly to the "Siamese" itself, which causes it to stand steady under any pressure, the men being required simply to direct the stream, and not hold the pipe. By the use of adjustable screw-valves it is possible partially or fully to close either line, as desired. The three-way "Siamese" connection is shown separately in Fig. 18.

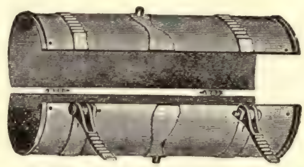


Fig. 19.—Neely's leak-stop.

IV. Hose-repairing Device.—For repairing bursted hose quickly and without delay various devices are provided. The ordinary hose-jacket is simply a wrapping of leather or other material applied to the hose by straps and buckles. Allen's hose-jacket, after passing around the hose has its edges brought together by a clamping-screw. Neely's leak-stop (Fig. 19) has two semi-cylindrical portions hinged together and lined with rubber, which receive the body of the hose between them. Hinged to one portion are swinging rack-bars, the teeth of which engage with fixed corrugations in the other portion, and which thus bind and hold both parts together.

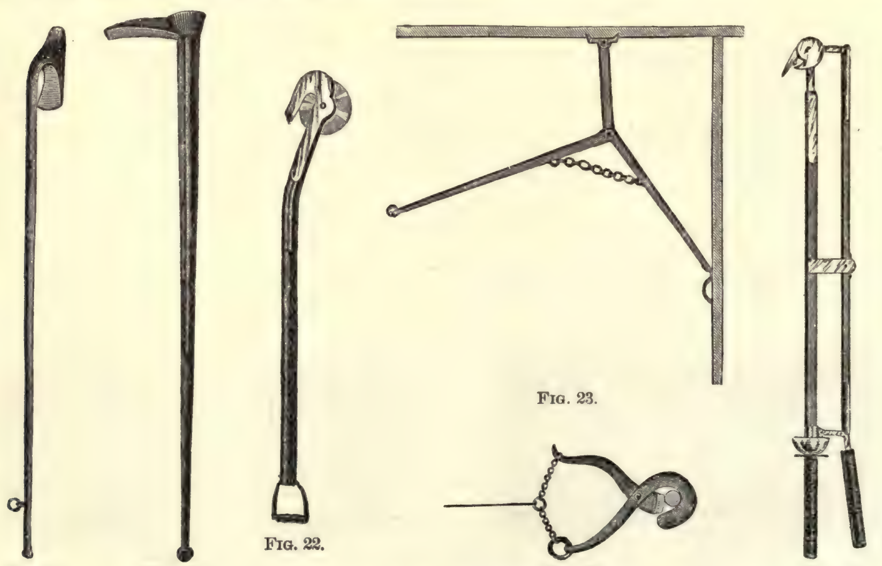


Fig. 20. Fig. 21. Fig. 22. Fig. 23. Fig. 25. Fig. 24.

Figs. 20–25.—Fire tools.

Fire-Tools.—A variety of the latest improved fire-tools and appliances are illustrated in Figs. 20 to 25. Fig. 20 is a tool for taking off the iron shutters of windows. The bent-over extremity is placed over the edge of the shutter, and, by pulling on a rope attached to

the tool, the shutter is torn from its hinges. Fig. 21 is a "fireman's jimmy," or claw-bar, used for opening doors. gratings, etc. Fig. 22 is a tin-roof cutter. The beak of the instrument is inserted through a hole made in the tin, and the user walking backward drags the implement after him, the rotary knife rapidly and cleanly cutting the roofing. Fig. 23 is a simple arrangement of levers used for breaking open doors. Fig. 24 is a rotary cutting instrument provided with insulated handles, and used for cutting live electric-light wires without danger to the person handling it. Fig. 25 is a device for cutting iron bars commonly used as window-guards.

FIRE-ARMS. I. Rifles.—Single-shot arms have almost wholly given place to those having a repeating or magazine construction for sporting purposes, and have been completely superseded by the latter for military use.

The Winchester Repeating-Rifle during the last decade has appeared in various improved forms. We illustrate the latest, known as the 1890 model, in Fig. 1, which shows the weapon in its entirety, and also in section closed. The system is a new one, with a sliding fire-arm

Fig. 1.—Winchester rifle.

movement, and is especially suited to small cartridges. The breech-block locks itself in plain view, and is of such size as to permit a strong firing-pin and extractor and offer a good cover to the cartridge-head. The gun locks at each closing movement and can not be opened except by letting down the hammer or pushing forward the firing-pin. The parts are few and interchangeable. The gun can not be prematurely fired, nor can the hammer be pulled other than at the proper time.

In charging the magazine the milled-head at the top is turned until the tube is unlocked. The inner tube is drawn out until it strikes the stop. The loading-hole is thus opened so that cartridges can be dropped into the magazine until the latter is filled. The magazine of the ·22 short-gun will hold fifteen ·22 short Winchester cartridges. After the magazine is filled the inner case is pressed down, turned, and so locked. When the hammer is down, the motion of the handle backward and forward unlocks, opens, and cocks the gun, forces the cartridge into the chamber and locks the piece. The gun once closed is locked, while the hammer stands at full or half cock. To open the gun without firing or letting down the hammer the firing-pin is pushed forward and the handle simultaneously pulled backward. When the gun stands at half cock it is locked both as to the opening of the breech and the pulling of the trigger. The hammer can not be cocked by the motion of the breech-block from this position, but must be cocked by hand.

The Lee-Speed or English Magazine Rifle, represented in Figs. 2, 3, 4, is the military weapon recently adopted by Great Britain. The illustrations exhibit the principal parts of the bolt-action. The mode of operation of the bolt-action is as follows: The bolt moves backward and forward along the axial line of the barrel. When it is forward, its end fits into the opening of the barrel, closing it and forming a breech-block. When it is back it leaves a recess, into which a cartridge may be dropped or fed, and when it is again pressed forward it drives the cartridge before it into the barrel, ready to be fired. There are, however, other operations to be performed besides putting the cartridge into the chamber. The bolt must be securely locked so that it can not be driven backward by the powder-pressure into the soldier's face; the mainspring must be compressed ready to drive the striker against the base of the cartridge, and after the charge has been fired the cartridge must be extracted and the empty case thrown out. The locking of the bolt is affected by rotating it on its axis so as to bring its rib behind a projection or snug on the body. In this position it is impossible for the bolt to be driven out, unless it should double up under the endwise pressure. The mainspring, which is contained in a recess in the center of the bolt, is compressed by the rear part of the striker meeting with the sear before the bolt is home. The further movement of the bolt then compresses the spring, which is subsequently released by the trigger. The extractor is a hook pivoted to the head of the bolt, and springs over the rim on the base of the cartridge when the latter is driven home. It often requires a very considerable amount of force to dislodge a cartridge, which, of course, becomes expanded by the explosion. It is customary to effect this at two operations; first it is started a distance of $\frac{1}{16}$ in. to $\frac{1}{8}$ in. by a rotary movement of the bolt, and then it is pulled out by the straight backward motion. A lug on the bolt, taking into a spiral groove in the body, accounts for the first small motion. Turning to the arm before us it will be seen that the body is cut away at the top and bottom (Fig. 1), to allow cartridges to be fed in by hand from above, and also to be pushed up from below out of the magazine, according to circumstances. When the magazine is out of action the car-

tridges are prevented from rising by means of a cut-off. This is a plate pivoted near the front end and provided with a thumb-piece projecting on the right-hand side of the stock (Fig. 2). By pushing this cut-off in it partially covers the mouth of the magazine, and forms a bed for a cartridge to be laid on by hand. By drawing it out it leaves a clear opening for the cartridges to rise from below. There is sufficient of the body left to form a guide to the bolt, and prevent it falling out. At the extreme rear end the bolt is embraced around about three quarters of its circumference, while a guide is formed for the long-rib (Fig. 4), which constitutes a portion of the bolt and prevents it being rotated until it is nearly home. The head of the bolt, with the extractor, which does not share in the rotation of the bolt, is guided by a lip which takes around an undercut rail on the right-hand side of the breech. This piece (Fig. 2) simply moves backward and forward, and is never turned on its axis. It is secured to the bolt by a turned shank, which fits into the latter, and is prevented from drawing out by a set-screw (full-size in illustration). This set-screw passes through the dust-guard and is screwed into the bolt; its point projects into a slot (Fig. 4) formed in the shank of the head to the extent of about $\frac{1}{10}$ in. This slot is of considerable length, to allow of the relative motions of the bolt and its head. The extractor is a hook set in a slot in the bolt-head; it is pivoted on a small screw and is pressed down by a spring, so that it may always catch over the rim of a cartridge. The bolt is bored from end to end. Through the center runs the striker. At the front this has a needle to impinge on the cartridge, and at the rear end (Fig. 1) a spindle to which is attached a cocking-piece that extends below the bolt and engages with the sear on the trigger. The mainspring surrounds this spindle inside the bolt. The cocking-piece is guided by a slot in the exterior of the bolt when the bolt is withdrawn, as in Fig. 1; and also, when the bolt is nearly home, by a groove in the lower side of the body. The cocking-piece does not share in the rotation of the bolt, and to admit of the relative motions two longitudinal grooves are formed in the outside of the bolt, and these

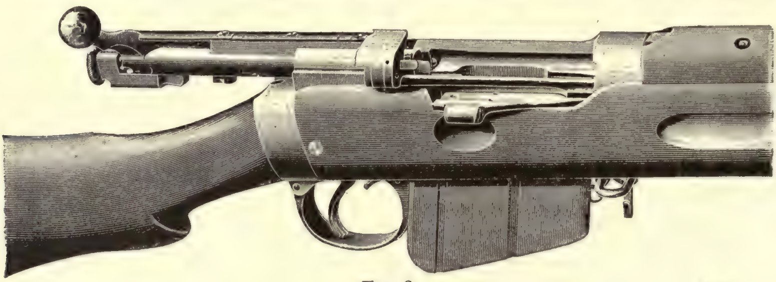


Fig. 2.

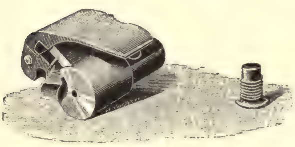


Fig. 3.

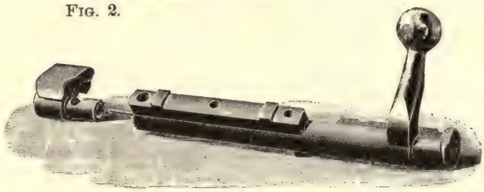


Fig. 4.

Figs. 2–4.—English magazine rifle.

two grooves are united by a short inclined groove, A lug in the cocking-piece works in these grooves and prevents the rifle being fired before the bolt is securely locked.

The magazine is formed of sheet-steel and fitted into a slot cut in the stock. When in place it is held by a catch, which can be withdrawn by the small trigger shown in front of the main trigger in Fig. 1. Inside the magazine is a platform or false bottom mounted on a spring, and on this platform the cartridges are placed to the number of eight. When the magazine is full the spring is folded quite flat, and the platform is at the bottom of the magazine. The cartridges are prevented from being shot out by the spring by two short turned-in lips at the mouth, under which the rear ends are inserted in filling. The rims project sufficiently above these lips to be caught by the bolt-head, while the points are pressed up by the spring to clear the other end of the magazine. By the time the rim is clear of the lid the bullet is, or should be, in the chamber of the barrel. The soldier is supposed to carry a second magazine fully charged in his pouch, and in a moment of emergency he can discard the first and substitute for it the second. If he does not do this he can refill the first without removal by putting in cartridges, one by one, through the breech of the gun. The cartridges are solid-cased. The bore of the barrel is ·303 in., and the rifling is on the modified Metford plan. A full discussion of the merits and demerits of this arm will be found in *Engineering*, February 6, 1891.

The Mannlicher Magazine Rifle, adopted by Austria, is represented in Fig. 5. The most striking feature of this arm is that it is not designed to be used as a single-loader. At all times the soldier uses his magazine, no matter how deliberately he may take aim. Instead of being issued singly to the soldier, the cartridges are sent out in packages of five (Fig. 7), held together by a light steel clip, and the whole five, with the holder, are placed in the

magazine with more ease than one, since they present a better finger-hold. At each backward and forward motion of the bolt a cartridge is pushed out of its holder, forced into the barrel and extracted, and as soon as the last has been removed, the holder drops through a hole in the bottom of the magazine and falls on the ground. Another point of interest is that the bolt has no turning-motion on its axis. It is pushed straight in and out, and is locked by a drop-catch. The moment it is home the catch takes against a fixed projection in the body, which resists the rearward action of the powder-pressure. The first action of drawing back the handle of the bolt is to lift the drop-catch over the projection, when the bolt can be readily withdrawn, bringing the empty cartridge-case with it. The magazine is not intended to be removed, and is fitted with a spring, the platform of which always remains parallel to the cartridges, and directs their points to enter the chamber. Fig. 5 shows the body of the rifle with the bolt drawn back. The top cartridge in the magazine can be seen standing ready to be driven into the chamber. When the bolt is moved forward its round end (Fig. 6),

FIG. 5.

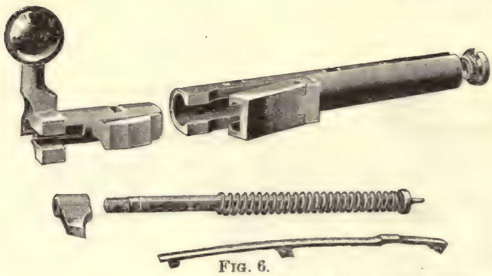


FIG. 6.

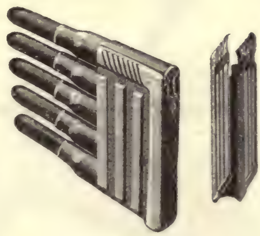


FIG. 7.

FIGS. 5-7.—Mannlicher magazine rifle.

beyond which the extractor projects, catches the base of the cartridge standing in the clip or cartridge-holder (Fig. 7). Before the cartridge is free from the clip the bullet is entirely within the chamber, and forms a guide to lead it forward. When the clip ceases to hold the rear end of the cartridge, the extractor catches it and presses it against the hollowed side of the body, along which it slides into its place. There is no chance of a jam taking place, however fast the feeding may be effected, since the cartridge is held both at front and rear. The magazine-spring lies partly within the steel clip without touching it. As soon as one cartridge is removed the remainder are all pushed up, the pressure of the upper cartridge against the turned-in sides of the holder supporting the latter; as soon as the last cartridge is put into the barrel this pressure is, of course, withdrawn, and the empty holder drops down, leaving a clear space for the insertion of another. The spring is formed of two blades; the lower is pivoted near the bottom of the magazine by one of the screws shown, while the second is pivoted to the first. At each joint there is a strong spring of considerable range, so that the cartridges are pressed up steadily and firmly to the very last. This pressure is resisted by a catch or rib on the back of the holder, which takes against a small catch provided with an external pressing-piece at the back of the magazine. This piece can not be seen in the engravings. The bolt is made in two pieces, the main part being bored from end to end. In its center lies the striker with the mainspring, and in a groove in its side is the extractor (Fig. 6). The front end of the bolt is closed by a screw, having a small hole in it for the striker to pass through. In the head of this screw is a gate which receives the extractor; by this means the screw is locked and can not chatter back. Into the back of the bolt there slides the handle, the two being held together by the striker and spring, as by an elastic bolt. To the end of the striker is screwed the cocking-catch, which engages with a sear on the trigger. On the under side of the handle-piece is a fixed incline, which the mainspring constantly tends to draw in between the bolt and the drop-catch on the latter. This action, however, can not take place until the bolt has been pressed in so far that the drop-piece (Fig. 6) has arrived over a cavity cut in the gun-body to receive it. Immediately this position is attained, the handle-piece can be pushed forward to lock the bolt. At the same time the cocking-catch hooks on the sear, and the piece is cocked ready for firing. In extracting, the handle is first drawn back to lift the drop-catch over the projection; during this time the bolt stands still. Further motion carries the bolt back, and with it the extractor and the cartridge. (See *Engineering*, March 6, 1891.)

The Mauser Magazine Rifle, represented in Figs. 8 and 9, has been adopted by the Belgian, the Turkish, and the Argentine Governments. It has a magazine which, although not absolutely fixed, is not intended to be removed except at considerable intervals for purposes of cleaning. The cartridges are issued in sets of five, held together by clips or holders, but these clips do not go into the magazine, and form no part of the equipment of the rifle. The cartridges in their holder are placed directly over the mouth of the magazine, and by pressure of the thumb are fed out of the holder into the magazine. Fig. 8 shows the body of the weapon, with the bolt drawn back and the magazine full. Fig. 9 shows details.

The system of loading by means of a temporary clip is clearly brought out in the engravings. The clip itself, *k*, is a piece of thin plate steel bent over at its edges to form a groove or rebate, in which the flanges at the bases of the cartridges fit. This groove is open at either end, so that the cartridges are free to slide out. To prevent them chattering out during transit, a light spring, made of a piece of steel ribbon, is laid in the bottom of the groove and holds the flanges of the cartridges firmly against the turned-over edges of the steel strip. But if pressure be applied to the cartridges in a line parallel to the clip, then they can be readily made to slide out of the groove. Provision is made in the body of the rifle for holding the clip perpendicularly, or nearly so, over the mouth of the magazine in such a position that a moderate pressure applied by the thumb to the upper cartridge will feed the whole of them downward into their places. The clip is left standing, supported at the sides and the bottom by the solid metal of the rifle body, and held by the elastic pressure of the piece *f*. The first movement of the bolt throws out the clip, and the piece *f* springs back into place.

In the Mauser magazine the cartridges are pushed in sidewise instead of endwise, and yet the spring does not force them out again as soon as the pressure is withdrawn. This results from the construction of the magazine, *i*. The lips are turned over for nearly the entire length, but they are divided by a straight cut from the sides, and are so elastic that they readily

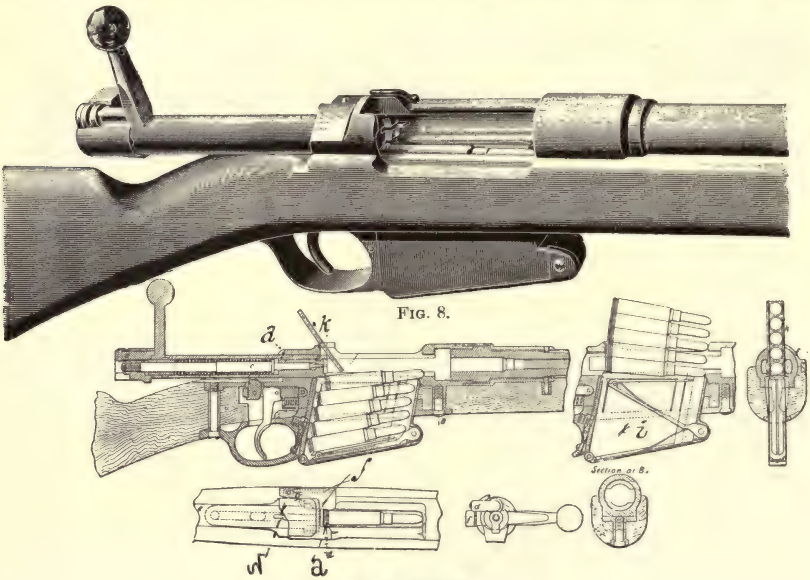


FIG. 8.

Fig. 9.—Details.

FIGS. 8, 9.—Mauser magazine rifle.

spring apart to receive a charge. They are, however, sufficiently strong not to be opened by the elastic pressure which forces the cartridges upward. The base of the top cartridge projects above the mouth of the magazine sufficiently to be caught by the bolt *a* when it is moved forward, forcing the point of the bullet up an incline into the barrel, and thus springing apart the lips of the magazine to allow the cartridge to escape from it.

The feeding arrangement is formed of two leaves, each acted upon by a spring. The bottom of the magazine is pivoted at its rear end, and secured by a screw at its forward end. If this screw be withdrawn a few turns, the bottom of the magazine, with the spring attached to it, drops down, and a few turns more enable the feeder to be detached and withdrawn. By pressing on the button which comes through the front of the trigger-guard, the catch-lever can be withdrawn and the magazine liberated.

The bolt is merely a hollow cylinder of steel with a handle at one end and two locking-lugs at the other, which slide through two grooves in the breech of the gun, and on the bolt being rotated lock behind two projections. In fact, they constitute an interrupted screw. The strain of the explosion is thus borne by the base of the bolt and the breech of the barrel, and is not transmitted through the body. The gate, which is cut through one of the locking pieces on the end of the bolt, is made to accommodate the piece *f*. A blade hinged to this

piece projects into the body of the rifle, and passes through the gate when the bolt is drawn back. This gate is so deep that the blade is pressed by a spring into the path of the empty case, forcing it out of the grasp of the extractor, and flinging it sidewise out of the arm on to the ground. Also connected to this piece *f* is a stop which normally prevents the bolt being drawn out of the gun. But by pressing back the piece with the thumb the stop is withdrawn, and the bolt can be removed in less than a second. It can then be taken entirely to pieces in a couple of minutes, and this without tools. To lock the rifle, so that it may not be accidentally fired, there is provided the safety appliance *d* on the end of the bolt. This is a short spindle with a cam at each end, and a roughed thumb-piece by which it can be turned half-way round. When the spindle is rotated the cam at the front end takes into a recess on the end of the bolt, and locks the latter against being turned, while the cam at the rear end inserts itself before the nut on the end of the striker, and holds it fixed. The barrel is turned parallel to two diameters, the front portion being rather more than half the length. The body is secured to the wooden stock, but the barrel is only clipped to it, and is left perfectly free to expand and contract. It lies in a deep groove in the wood, and is held by parallel clips, which serve as guides. The bore of the barrel is 7·65 mm. (·301 in.). The front sight is a barleycorn. The back sight is marked up to 2,050 metres.

The relative differences in operation between the Lee-Speed, Mannlicher, and Mauser rifles may be summarized as follows:

Type I. *Lee-Speed.*	Type II. *Mannlicher.*	Type III. *Mauser.*
Designed to be used as a single-loader until the supreme moment.	Designed to be used always as a magazine rifle. Can be used as a single-loader with the magazine empty.	Designed to be used indifferently as a single-loader or as a magazine-rifle.
Fires 16 shots very rapidly, with a brief intermission after the first 8. After that a long interval, or else single loading must be resumed.	Fires series of 5 shots with very short intervals between.	Fires series of 5 shots, with very short intervals between.
Average rate of firing not greater than a single-loader.	Average rate of firing greater than a single-loader.	Average rate of firing greater than a single-loader.
There is no cartridge-holder.	The cartridge-holder is essential to the feeding-action of the magazine.	A cartridge-holder is used to increase the speed of loading, but does not enter the magazine.

(See *Engineering*, April 3, 1891.)

The German Repeating-Rifle is represented in Figs. 10 and 11, and, as it represents the practice of the foremost military nation in Europe, is of especial interest. It is of the same

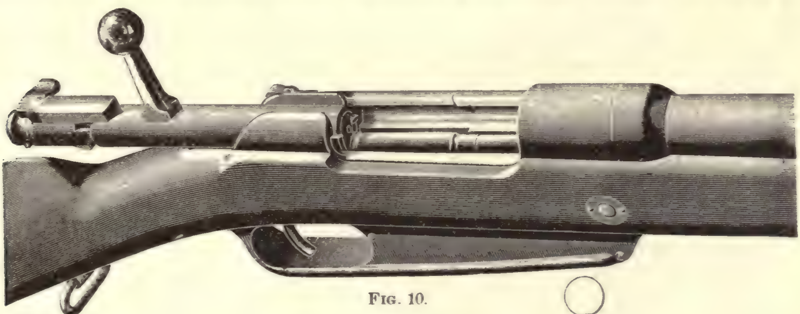


Fig. 10.

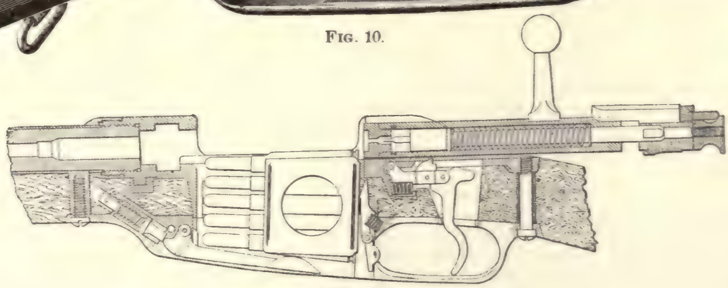


Fig. 11.

Figs. 10, 11.—German repeating rifle.

type as the Mannlicher arm above described. The distinctive feature is the method of issuing and loading the cartridges. These are arranged in packets of five, held together by a light steel clip. The packages, including the clips, are placed in the magazine. The cartridges are fed upward one at a time, and, when the last is loaded into the barrel, the clip falls out of

the bottom. The breech is closed by a bolt, which turns down over the magazine. At its forward end this bolt has two lugs, which enter the rear of the chamber in the barrel and lock behind two projections therein. The projections are tapered at one part, so that when the bolt is turned to lock it, it also advances about $\frac{3}{8}$ in. In unlocking, this motion starts the cartridge. The extractor is mounted on the end of the bolt in front of the lugs. It is let into the side of the loose head, and is secured by the sides of the groove in which it lies, being slightly hammered over. At the opposite side is a disengaging-pin, which is designed to throw out the empty cartridge-case when the bolt is drawn completely back. In Fig. 10 the end of the pin has struck against a stop in the body, and has been suddenly forced forward, tilting the cartridge-case over to the right and out of the arm. The stop against which the pin strikes, as well as a large stop which stands in the path of the lug, are both mounted on a pivoted spring-arm, and can be instantly withdrawn when it is desired to remove the bolt from the gun. The body of the bolt is exceedingly strong and solid ; the handle is firmly attached to it, and could not be broken off by any violence. The bolt is bored from end to end, and within it are placed the striker and the mainspring. As already stated, the former has a flat head entering a slot in the extractor, while its point projects right through to reach the cartridge. The rear end of the striker is screwed to receive a nut, which holds all the parts together. It also carries the cocking-catch, which is guided partly by the bolt and partly by a long finger which projects over and bears upon the bolt. A bent on the lower side of the catch also slides in a groove through which the sear of the trigger projects. The cocking is effected by means of two cam-paths, one cut into the wall of the bolt, and the other forming a spur or projection on the cocking-catch. Supposing the arm to have just been fired, these two surfaces lie together, and the bolt forms one continuous cylinder with the cocking-catch. When the bolt is rotated to unlock it, the cocking-catch can not turn at the same time, because its finger lies in the slot cut in the body. The two inclines, therefore, move over one another, and the catch is forced back until the point of its incline rides on the flat end of the bolt. The bolt is now drawn back to extract the empty cartridge, and then forced forward to load a full one. In its progress the cocking-catch meets the sear of the trigger, and is held by it, so that when the bolt is turned these inclines come opposite each other, and the full force of the spring tends to drive the striker forward as soon as the trigger is pulled. If the trigger should be pulled before the bolt is locked the one incline strikes the other, and so prevents the striker reaching the cartridge. There is a safety-catch by which the bolt can be locked, and rendered incapable of being fired until the catch is turned back. This consists of a spindle cut away on one side for a part of its length, and is provided with a thumb-piece to turn it. The spindle lies in a recess in the cocking-catch, and in the finger which projects from the latter. In the position shown in Fig. 10 the spindle offers no opposition to the cocking-catch going forward, but if the thumb-piece be turned over to the other side, the uncut end of the spindle takes into a recess in the end of the bolt, and locks all the parts firmly together. The safety-catch also serves to lock the nut on the end of the striker-bolt. The spindle is pressed outward by a spring, and its round end takes into a similarly shaped recess in the under side of the nut. By pressing the spindle forward the nut can be released and turned. The magazine is exceedingly compact, and is combined with the trigger-guard, as it is not intended to be removed, except at rare intervals. The feeder-spring is a bell-crank, with one arm exceedingly short. This short arm is pressed upon by a plunger, around which is a coiled spring. This gives a very even motion, with little difference of pressure between a full and an empty magazine. The clip, with its complement of cartridges, is thrust into the magazine, and is held by the projection on its back taking into the catch in front of the trigger-guard. By pressing the knob on this catch the holder can be released, and will spring out upward. The following table gives the dimensions of the rifle:

Caliber	7·9 mm.
Total length	1·245 m.
Length of barrel	·74 "
Weight without bayonet	3·8 kilos.
" of bayonet	·55 "
Length of cartridge	82·5 mm.
" " projectile	31·6 "
Weight of cartridge	27·5 gms.
Weight of projectile with steel or nickel envelope	14·5 "
Initial velocity with a charge of 2·5 grammes of smokeless powder, measured at 25 metres from the muzzle	625 per sec.
Pressure	3,200 atm.
Greatest elevation for 500 metres	1·5°.
Lateral divergence at 600 metres	·64°.

Rifling, four grooves of 240 mm. pitch.
The projectile makes 2,580 revolutions the first second.
Range, 3,800 metres (4,150 yds.) with an elevation of 32°.
Sight graduated to 2,050 metres (2,230 yds.).

Perforation at 300 metres	7 mm. of iron.
" 100 "	800 " dry pine.
" 400 "	450 " "
" 800 "	250 " "

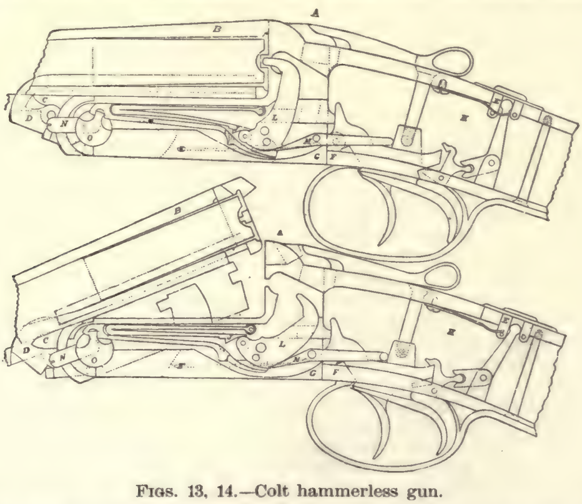
(See *Engineering*, May 15, 1891.)

The Schmidt Magazine-Rifle is represented in Fig. 12. This arm has been adopted by Switzerland. Its most striking feature is the large number of cartridges that the magazine

Fig. 12.—Schmidt magazine rifle.

contains, viz., 12. Accommodation is found for this large number, without the use of an unwieldy magazine by making them lie alternately right and left. In other words, the width of the magazine is about $1\frac{1}{2}$ time the diameter of a cartridge, and consequently it will admit a very considerable number without being of any great depth. The magazine is filled from packets of cartridges, each containing six; it therefore requires the contents of two packets to replenish it when empty. It can, however, be supplied with cartridges one at a time, like the Lee-Speed. By means of a "cut-off" the magazine can be put out of action, and the piece used as a single-loader. Under these conditions the reserve remains untouched until the supreme moment of the attack, when a rapid stream of bullets can be poured out. Should the contents of the magazine not be sufficient, a fresh supply can be inserted in 8 sec. The motion for operating the breech-action is entirely rectilinear, as in the Mannlicher system. The bolt is simply pushed in and out, and is not rotated. The locking of the breech-plug is effected at its rear end, at a very considerable distance from the breech. The extractor does not rotate round the cartridge-rim. We learn from the official hand-book of the Swiss Military Department that the rifle will fire 20 aimed shots a minute when used as a single loader. With the magazine in action it will fire 30 aimed shots in the same time, and 40 shots without aiming. The successive shots can be fired without removing the rifle from the shoulder. The weight is $9\frac{1}{2}$ lbs. The total length of the barrel is 30·7 in.; the caliber, ·295 in.; the number of grooves in the rifling is 3, and they make one turn in 10·6 in. The bullet is of hardened lead, in a steel envelope; its length is 1·13 in., its diameter ·32 in., and its weight ·0302 lb. The charge of smokeless powder is 31 grains. This gives an initial velocity of 1,968 ft. a second. A full description of the mechanism of this arm appears in *Engineering*, October 2, 1891.

II. Shot-Guns.—*The Colt Hammerless Gun* is shown open in Fig. 13 and closed in Fig. 14. The parts are as follows: *A* is the frame, *B* the barrel, *C* the fore-end, *D* the extractor cam,



Figs. 13, 14.—Colt hammerless gun.

E the safety-slide, *F* the trigger-plate, *G* the lock-cover plate, *H* the stock, *I* the screw-holes in the draw-bar, *J* the mainspring, *K*, the sear-spring, *L* the hammer, *M* the sear, *N* the cocking-pin, and *O* the body-pin. The operation is as follows: The gun is cocked first by throwing down the barrels, and second by bringing them back into place. An inspection of the drawing shows that the second motion increases the tension of the mainspring by push-

ing its inclined surface above the roll of the hammer, thus utilizing both motions of the barrels and making the forces required to open and close them more nearly equal. The mainsprings move on rolls, making the friction the least possible. The safety apparatus does not require the cutting away of the stock, so that the stock is very strong. The triggers are firmly secured by a positive-lock and not by springs. The hammers can be let down separately or together by pressing the safety-slide forward and pulling one or both triggers while closing the barrels.

The Parker Gun, manufactured by Parker Bros., of Meriden, Conn., is represented in Figs. 15 and 16, the arm being shown open at Fig. 16 and closed at Fig. 15. The mechanism operates as follows:

Pressing upon the finger-piece 1, in front of the guard 2, raises the lifter 3, and its beveled side coming in contact with the screw 4, acts as a wedge to draw the bolt 5 from the mor-

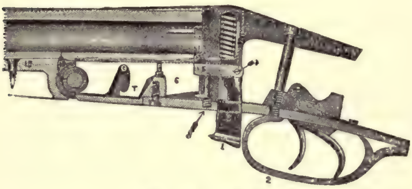


Fig. 15.—Parker gun.

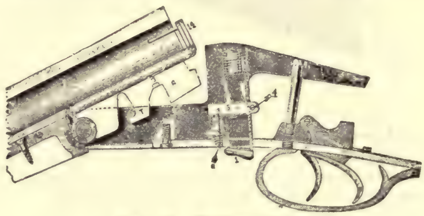


Fig. 16.—Parker gun.

tise which is cut in the lug 6, and releases the barrels, ready for the insertion of the cartridges. It will be observed that when the bolt 5 is back to the position, as shown in Fig. 16, the same hole which is drilled in the under side of said bolt comes directly over the trip 7, which, by the assistance of the small spiral spring 8, is made to enter this hole in the bolt 5, and thereby holds it in position. The finger-piece 1 is solid and a part of lifter 3. The action of the lifter 3 is positive, not only to withdraw the bolt from but to force it forward into the mortise in the lug 6. For the purpose of cleaning it can be very easily removed by taking off the locks and removing the small-screw 4 from the end of the bolt 5, when by pressing down on trip 7 the lifter can be withdrawn without removing either stock, guard, or trigger-plate. The improved roll 13 gives strength to the joint. When the barrels are brought to place for firing, the bottom of the lug 6 strikes the trip 7, withdrawing it from the bolt 5, which then enters the mortise in the lug 6 and securely locks the gun, as shown in Fig. 15. The mode of manufacturing the barrels of this gun is of interest, and is described by the makers as follows: Plates of iron and steel are arranged in layers and then welded into a compact bar, which must be absolutely sound and perfect, as the slightest spot left unwelded or unsound in this operation will be sure to cause a total loss of the barrel. The process consists in reducing this bar to such a sized rod as may be required for a certain weight of barrel. This rod is twisted similar to a rope, as shown at *E* in Fig. 17, care being taken to have the twist uniform and even. Several of these twisted rods are placed side by side, the inclination of the twist being in opposite directions, as shown in the illustration. These several rods are welded together with the same care and precision as in the previous operation. This is termed a ribbon and is coiled spirally around a mandrel, as shown at *F*, raised to a welding heat and jumped by striking the end against the anvil, thereby welding the edges firmly together. The ribbons are then placed upon a welding mandrel, reheated and welded from end to end. Much skill and care are required in this operation to reduce the outside diameter to correct size and at the same time preserve the caliber, and also maintain the proper taper, the barrel being much larger at the breech than at the muzzle. The fine figure that appears in the figured barrel is dependent upon the correctness of this and the previous welding operations, for, if hammered unevenly, the figure itself will be correspondingly uneven. Then follows the process of hammering in nearly a cold state, whereby the texture of the metal is condensed, closing its pores and making it harder. This finishes the operation of barrel-forging, and the barrel is now ready to be bored, turned, and finished upon lathes manufactured expressly for the purpose. The curly figure that appears at *G* is obtained by twisting the rods before referred to, as appears in the illustration at *E* in Fig. 17, the variation of figure being obtained by varying the piling. The white marks that appear in the finished barrel are iron and the dark ones the steel. A finer figure is obtained by an increased number of pieces in the operation of piling. This larger number of pieces necessarily renders the operations of securing perfect welding much more difficult, and the liability of loss is greater. Some people imagine that the curly figures of the barrel are simply etched on the outside, when they are, in fact, the visible proof of a superior strength, both desirable and important to every shooter who cares for his personal safety, for if an iron barrel, no matter how strong and thick, is defective and does not stand the test, the defective part will splinter into more or less small pieces, while the Damascus barrels will tear like woven fabric.

Fig. 17.—Parker gun-barrel.

The Whitmore Hammerless Gun, manufactured by the American Arms Co., of Boston,

Mass., is shown open and in partial section in Fig. 18. This arm contains, among other novel features, a triple wedge-bolt fastening and compensating devices, whereby any looseness in the mechanism due to wear can be corrected by simply adjusting a screw. The barrels can be attached to the stalk, whether the gun is cocked or not. The cocking-rod engages with the lever, which in turn engages with both hammers at the same time, so that the latter lock simultaneously. The lock is so constructed that it is impossible to introduce a loaded shell into the gun before the latter is cocked. Another novel feature is the compensating screw in the sears which comes in contact with the hammer, forcing it into cock positively in case a sear-spring should break. The mainsprings being swiveled to the hammers, friction is reduced, consequently the gun cocks with remarkable ease. A strong block of steel is forced over the triggers by the double bolt pushing a steel rod on opening the gun. By holding on to the hammers and closing the barrels, the hammers can be let down without snapping. The safety can be made automatic or independent by turning a small screw in the lock-plate in front of the trigger-guard.

FIG. 18.—Whitmore gun.

The Baker Gun, made by the Baker Forging and Gun Co., of Batavia, N. Y., is chiefly remarkable for its simple construction and low price. The rebounding-lock has but four pieces. The mechanism is clearly shown in Fig. 19.

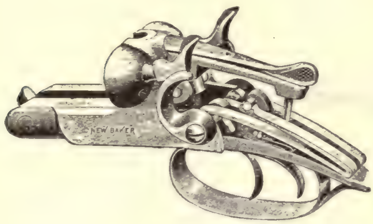


FIG. 19.—Baker gun.

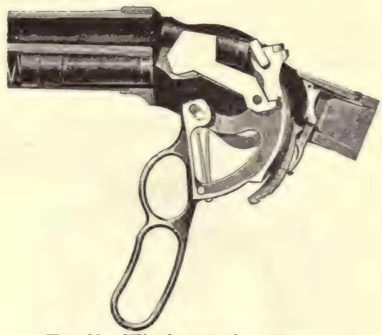


FIG. 20.—Winchester shot-gun.

The Winchester Repeating Shot-Gun, manufactured by the Winchester Repeating Arms Co., of New Haven, Conn., is illustrated in open position in Fig. 20, from which the system, which contains but 16 parts in all, will be readily understood. The breech-block and finger-lever form one piece, and move together in opening and closing. The hammer, placed in the breech-block, is automatically cocked during the closing motion, but can also be cocked or set at half-cock by hand. The trigger and finger-lever are so adjusted that the trigger can not be pulled prematurely, and the gun can not be discharged until closed. The barrel can be examined and cleaned from the breech. The magazine and carrier hold five cartridges, which, with one in the chamber, make six at the command of the shooter.

This gun is made in both 10 and 12 gauges; the 12-gauge gun will handle shells $2\frac{5}{8}$ in. long, or less, and the 10-gauge will handle shells $2\frac{7}{8}$ in. long, or less.

To fill the magazine, throw down the lever and push four cartridges through the carrier into the magazine, placing the fifth in the carrier. The forward and backward motion of the finger-lever, which can be executed while the gun is at the shoulder, throws out the empty shell, raises a new cartridge from the magazine and puts it into the barrel. The gun is then ready to be fired The standard length of barrel is 30 or 32 in.

III. REVOLVERS.—*Colt's Double-Action Self-Cocking Revolver*, made by the Colt Patent Fire-Arms Mfg Co., of Hartford, Conn., is represented in Figs. 21 and 22. Fig. 21 shows it closed, and Fig. 22 with the cylinder swung out, the ejector being represented in the act of throwing out the empty shells, after which it will be automatically returned to its place in the cylinder, which will then be ready for loading. The cylinder contains six chambers. In order to facilitate the loading of cartridges and to allow the simultaneous ejection of the emptied cartridge shells, the cylinder is so mounted upon a crane pivoted in frame below the cylinder-seat that, on drawing the cylinder-latch to the rear, the cylinder swings to the left and downward out of its seat in the frame; in this position all the chambers are presented for loading, while pressure against the end of the ejector-rod under the barrel ejects all the shells. When, after ejecting and loading, the cylinder is returned to its seat in the frame, the cylinder-latch automatically secures it there. By this construction it is pointed out that all the facilities for loading and ejecting are obtained without sacrificing the important feature of a solid frame, such as all modern Colt pistols show, there being no hinge or joint in the frame between the barrel and stock, the wearing of which might disturb the accuracy of the

pistol. The hammer may be cocked by the thumb or by the trigger, and after firing it rebounds, and is positively locked in this safety position, so that it can not strike the primer of

FIG. 21.—Colt's revolver.

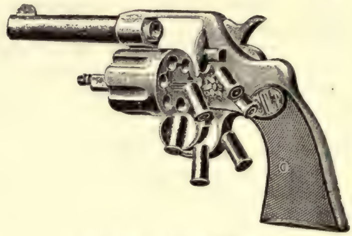


FIG. 22.—Colt's revolver.

a cartridge until it is again cocked. The cylinder can not be swung out of the frame unless the hammer is in its safety position, and the act of swinging the cylinder out of the frame automatically locks the trigger and the hammer in this position. Thus premature discharges during manipulation are prevented, as also accidental discharges from blows, such as result from a fall, etc. The falling of the hammer from any position can not fire a shot unless the trigger is fully pulled back at the same time, as only then the hammer can fall beyond the safety position. The hand or pawl which rotates the cylinder has two working points to engage the cylinder-ratchet, and, by an ingenious construction, this pawl also serves as cylinder-bolt, and positively prevents any further rotation after one of the chambers in the cylinder coincides with the bore of the barrel. The cylinder-latch prevents its backward rotation. We are advised that it was the feature of the jointless, solid frame, combined with the simultaneous ejection and its other good qualities, which caused the officers of the Bureau of Ordnance to adopt this revolver for the service of the United States Navy.

FIG. 23.—Colt's target revolver.

Colt's Special Target Revolver (Fig. 23) is substantially the same in action as the single-action revolver in use in the United States Army, and adopted by the War Department in 1873. The manufacturers in this pistol, however, have sought, by refinements in the sights and in the rifling, to attain great accuracy of fire, and the results are notably successful. A sample target, showing 25 consecutive shots at 12 yds. off-hand, made with a ·44-caliber arm by an expert marksman in December, 1890, is given in Fig. 24. This pistol has made a remarkable record in many competitive trials, both in the United States and abroad.

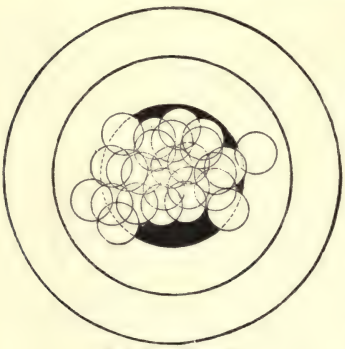


FIG. 24.—Target.

The Smith & Wesson Hammerless Safety Revolver, manufactured by Messrs. Smith & Wesson, of Springfield, Mass., is represented in Fig. 25. The especial feature of this arm is that the hammer, concealed within the lock-frame and operated by the trigger, as in any self-acting pistol, is constantly locked by the safety-latch, which is held in position by a spring. When held in the hand for firing, the natural pressure upon the safety-lever in the movement of pulling the trigger raises the safety-latch and releases the hammer. The safety-lever and trigger must act in unison, and to discharge this arm in any but the proper manner is an impossibility. It is well known that a very large proportion of the accidents with revolvers arises from some unintentional manipulation of the hammer. Either it receives a blow, is allowed to slip off the thumb in cocking, is accidentally caught on some foreign object and partially raised, or is unintentionally left at full-cock. The only other and a fruitful source of accident is the unintentional manipulation of the trigger. It will be apparent that the above-described construction prevents such casualties: first, by placing the ham-

FIG. 25.—Smith and Wesson revolver.

mer of the arm entirely within the lock-frame, so that no external force whatever can be applied to it; and, second, by so arranging the trigger that it can not be pulled except at the instant of deliberate firing, and only by this means.

The Colt Cartridge-Pack, illustrated in Fig. 26, is an ingenious device by which all chambers of a revolver can be loaded at one motion. The engraving shows the pack assembled, and also its parts. To assemble the pack the cartridges are placed with the bullets in the holes of the loading-blocks, shown on the left; the ring is placed over the heads of the cartridges, and the central plug is introduced into the ring and between the cartridges, which binds them firmly together. In using the pack, the pistol is held with the left hand, the cylinder being swung out, the right hand places the pack against the rear of the cylinder, and, grasping the ring, pushes it toward the cylinder, when the cartridges all enter the chambers and the plug escapes to the rear.

FIG. 26.—Colt cartridge pack.

Fire-Boats: see Engines, Steam Fire. **Fire-Engines, Chemical, Fire-Extinguishers**: see Engines, Fire, Chemical. **Fire-Proof Construction**: see Safes and Vaults and Terra-Cotta Lumber. **Fire-Tools**: see Fire-Appliances.

FIRE-ESCAPES. Apparatus for allowing egress from buildings on the exterior, instead of by the stairways or other ordinary means, are classed as fire-escapes. Three principal types may be recognized: (1) Those which are permanently arranged on the fronts of buildings; (2) those which are adjusted in position from the outside; and (3) those which are placed in windows and serve simply as means for lowering individuals.

An example of the first class is shown in Fig. 1, which is a combination of a stand-pipe with a ladder and one or more balconies. The stand-pipe is a wrought-iron pipe having an outlet at each floor and at the roof, at which points means are provided for the attachment of

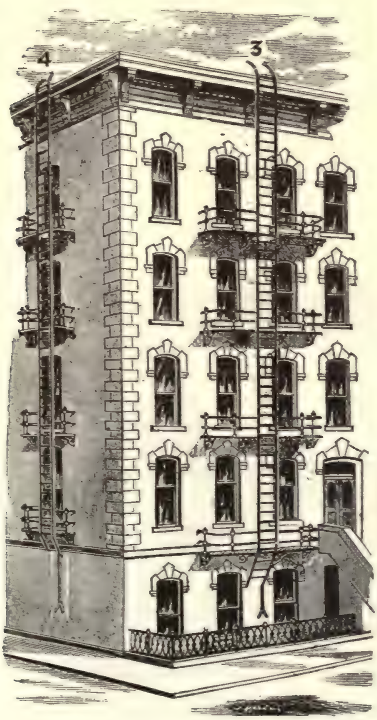


FIG. 1.—Permanent fire-escape.

FIG. 2.—Adjustable fire-escape.

hose. At the bottom of the pipe is a 2-way Siamese connection, so that two fire-engines may simultaneously pump into the pipe, whence streams may be taken at any floor or at the roof. The iron ladder is bolted to the pipe, and is made with rounds of angular cross-section,

so as not to retain ice and to afford a sure footing. The balconies are also of iron, and, being securely anchored to the wall, form a vantage-ground for the firemen, from which they can cope with the flames on a level with them and from the outside of the building. An example of the second class of fire-escape is given in Fig. 2. Here is shown a series of three connected ladders, one sliding upon the others. The three may be brought into prolongation by means of a simple chain and windlass. The ladder in position to raise is represented at 1. At 2 it is elevated and ready for extension. At 3 it is shown fully extended and ready for service. The length of the three ladders jointly is 70 ft. The upper or top ladder is held in position not only by the elevating chain, but by two supporting hooks, which automatically clasp the rounds, and also by self-acting brakes, so that in event of breakage of the chain the ladder can not slide down. An example of the third class of fire-escape is given in Fig. 3. The lowering rope is fastened securely to the wall, usually near the window-casing. It passes around a fixed bar in the lowering device and then between the parts of a brake or clamp, which is provided with a hand-lever. A belt or sling, as shown in the figure, is connected to the lowering device, and supports the person, who, by manipulating the brake, allows himself to slide down the lowering rope as rapidly or slowly as may be desired.

Fig. 3.—Fire-escape.

FLANGING-MACHINES. A variety of new forms are presented.

The Davis Flanging-Machine.—Fig. 1 represents a boiler-head flanging machine, built by I. B. Davis & Son, of Hartford, Conn., designed for flanging heads of any size from 38 to 96

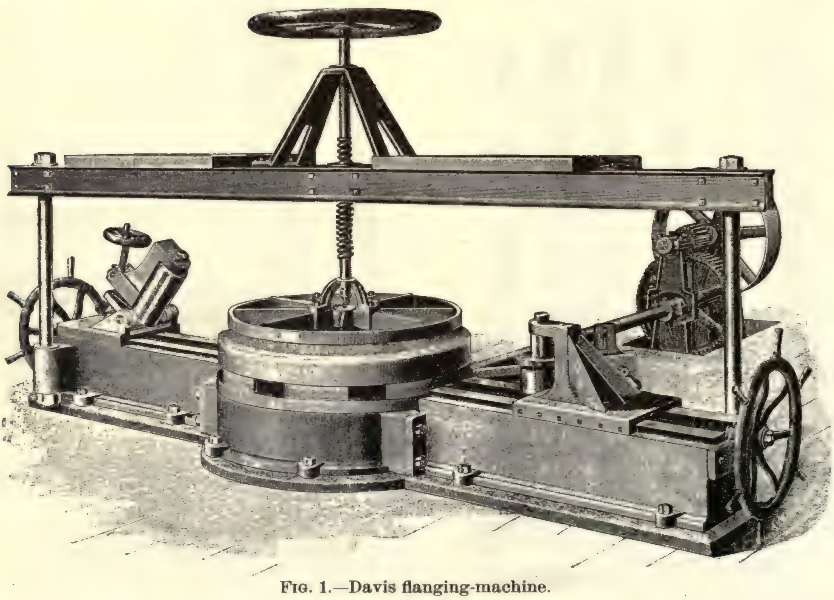


Fig. 1.—Davis flanging-machine.

in. diameter, and of any thickness required within those limits of size. In the center of the machine is a revolving plate, driven by a powerful train of gears, and which is adapted to receive and drive the former over which the head is formed. At the back of the machine are two arms having T-slots, by which are attached gauge-blocks, having swinging pieces, by which the head is centered on the former. The follower plate is then brought down on to the

head by means of the screw and hand-wheel at the top. This follower is so made as to bear hardest at the outside, and comes down with an outward pressing motion, which keeps the

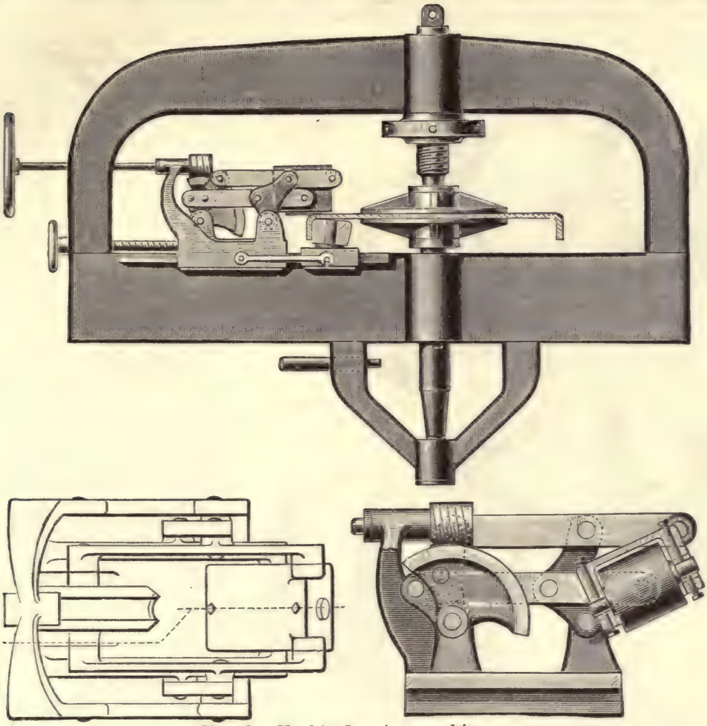


Fig. 2.—Clark's flanging-machine.

head straight and flat on the former while being turned. The machine is then set in motion, and the straight or "break-down" roll brought against the edge by means of the large screw in the bed. This roll is so mounted as to enable it to be presented at any desired angle, and can then be gradually brought to a vertical position by means of the hand-screw on the carriage, being kept up to the head at the same time by means of the large hand-wheel and screw. The finishing-roll, which is made of the shape it is desired the head to be, is at the opposite side of the machine, and is brought up to the head in the same manner, though it is fixed in a vertical position. As the first roll is bringing the edge of the head down to the former, the finishing-roll is brought up and completes the head. Hooks are placed in the follower, which take hold of the lower edge of the head, so that it is drawn off by means of the hand-wheel and screw on the top of the machine.

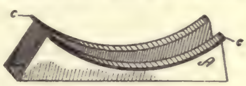
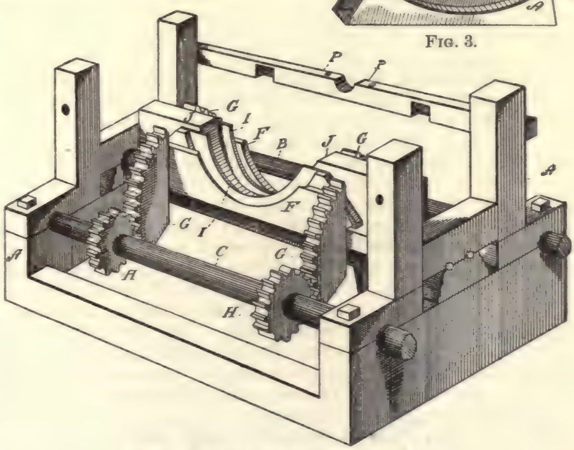


Fig. 3.



Figs. 3, 4.—Kent's flanging-machine.

Clark's Boiler-Head Flanging-Machine, made by Jacob Clark, of Germantown, Pa., is shown in Fig. 2. The plate to be flanged is clamped between two disks and rotated with its edge projecting over a short vertical roller. A swiveling-roller turns the flange down as the plate passes quite rapidly under it. This upper or swiveling roller is carried in a housing supported by two parallel levers, which are actuated by worm-gearing and hand-wheel, as shown. By the motion obtained by the combined action of the parallel levers the upper roll swivels from a horizontal to a vertical position, directly round the center of the fillet in the

head being flanged, giving a smooth, easy motion for the flow of the metal into its new form. The saddles carrying the two rollers are adjustable along the bed, thus making heads of varying diameters without formers. No hole is necessary in the plate. Heads of exactly uniform diameters are made as rapidly as the furnace can heat them.

Kent's Flanging-Machine.—Figs. 3, 4, 5, and 6 show a machine (patented by William Kent, February 15, 1887) for bending and flanging connecting pieces or saddles for water-tube boilers or shapes of similar construction in which two parallel plates of metal require to be flanged in opposite directions. The connecting piece to be made by the machine is shown in Fig. 3. Referring to Figs. 4, 5, 6, the following is a description of the machine: *A* is the frame of the machine. *B C* are shafts, having mounted thereon, outside the frame, gear-wheels, adapted to mesh with each other. *F F* are leaves pivoted between the sides of the frame so as to be capable of a swinging movement, while at the same time, when in their normal position they are in the same horizontal plane with the ledge between them, thus forming a platform upon which the blank may be placed. To the inside of each leaf are secured segment-gears *G*, with which mesh the cogs *H* on the shafts *B C*. Upon the blank *I* is superimposed an anvil, *J*, of suitable shape, according to the product desired. By turning the wheels external to the frame the cogs *H* will operate in conjunction with the segment-gears *G* to fold the leaves *F* upward. This operation is continued until the leaves have caused the blank to be bent at the desired angle (in this instance a right angle), when the blank is ready for the operation of the flanging mechanism, as seen at Fig. 4. The mechanism for flanging consists of a series of rolls, *L*, preferably three in number, the outside edges of all but one being beveled. These rolls are journaled within a box, *N*, secured on a shaft, *O*. This shaft *O* is mounted within suitable bearings on cross-pieces, *P*, secured to the frame, and is operated by gearing (not shown). As the shaft is revolved the rolls will gradually bend the edges of the blank and form thereon an outwardly projecting flange, as shown in Figs. 5 and 6.

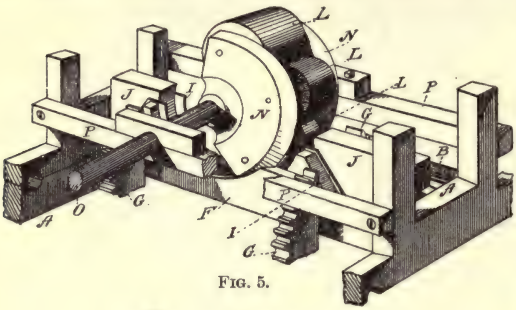


Fig. 5.

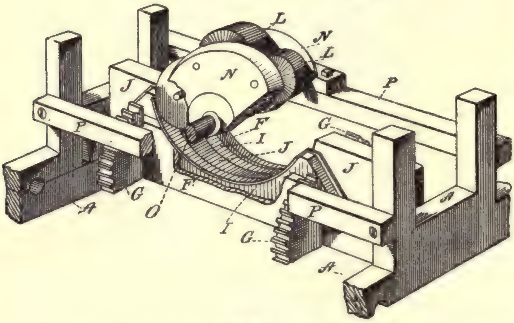


Fig. 6.

Figs. 5, 6.—Kent's flanging-machine.

FLAX-MACHINES. When flax is pulled, the stalk may be said to be made up of three distinct parts. There is first the wood, then the bark, and lastly the glossy varnish of the bark. The woody matter in flax is of no value; the difficulty is how to get rid of it and to save the bark. To accomplish this the flax must be retted, and it is either spread over a field and exposed to the weather for some time, which is called "dew-retting," or the straw is steeped in water. In a short time the vegetable part rots, the gum on the outside dissolves, and the stalks are taken out of the water and dried. But the wood is like a fixed finger inside a glove, and, although weakened, has still to be removed. Scutching is the process by which the wood is removed and the outside skin saved. The difficulty is to get the woody part out without injury to the skin, which is the valuable part of the plant and forms the flax-fiber. There are four methods of doing this. The first is by striking the flax repeated blows, then taking it in handfuls, holding it over a wooden rest, and striking it sharp blows with a wooden blade. The second plan is to run the retted straw through fluted iron rollers, and when the heart is thus broken into short bits to take the straw in handfuls and hold it against two end blades rapidly revolving upon a shaft. The process known as the "Cardon" process, and which promised great things a short time ago, consists in pricking the straw with needles. This cuts the straw into lengths so small as to make it practically dust. The straw comes easily away. But it is obvious that the skin is damaged at the same time, because the heart of the stalk must be got at through this outer skin.

The Spiegelberg Flax-Scutching Machine (Figs. 1 and 2).—A new scutching-machine has been devised by Mr. A. Spiegelberg, which is claimed to show material improvement over older devices. The flax-straw is fed into the machine, one end always overlapping the preceding one. Heavy fluted rollers flatten the tubular stalks, which action does not spoil the fiber, but only takes the resistance out of the straw. Then the flax proceeds to the small rollers, lightly fluted, just sufficient to obtain a thorough grip of the flax, and by means of suitable mechanism these rollers receive a lateral or shaking motion, which bends the stalks and al-

lows the wood to fall out, and also prevents the outer skin from becoming crushed or cut, as is the case with the needle-points, or the series of fluted rollers—run at a high speed—of other machines. The fiber then passes to the second part of the machine, as illustrated herewith, which somewhat resembles an intersecting heckling-machine. The "strike" of flax is secured between a pair of India-rubber gripping-rollers C C^1, which bring it into contact with a pair of rapidly revolving beaters D D^1. After this operation has gone on for a given time the beaters are caused to revolve in the opposite direction, the gripping-rollers C C^1 and E E^1 are respectively automatically opened and closed in the interval by means of cam-bars F F^1, and the cams G and levers H. In this manner both ends of the strike are sufficiently operated

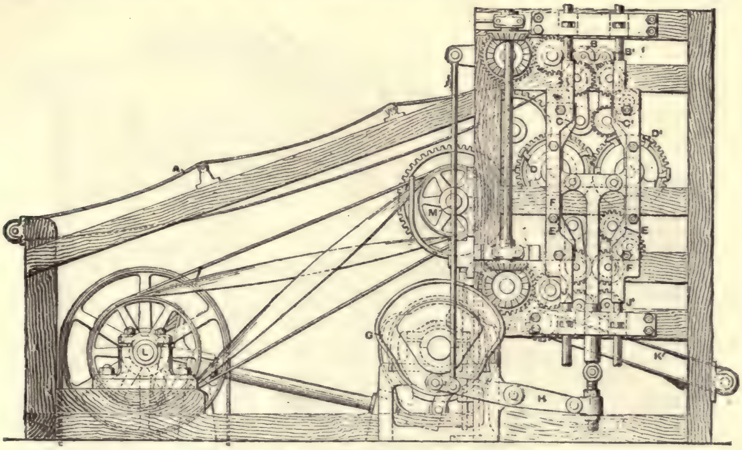


FIG. 1.

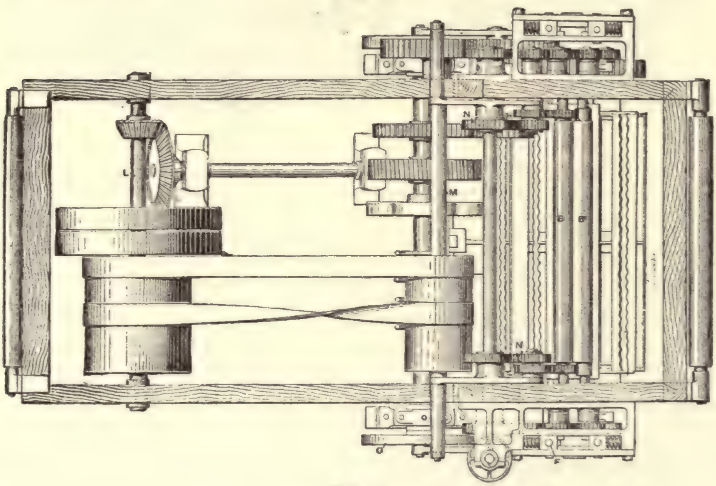


FIG. 2.

FIGS. 1, 2.—Spiegelberg flax-scutching machine

upon before they are allowed to proceed downward to the delivery roller J J^1, and thence to the delivery-apron K. L is the first-motion shaft, carrying fast and loose pulleys, connected with similar pulleys on the shaft M, from which the beaters are driven. The taking-in rollers B B^1 derive motion from suitable gearing N, which is so constructed as to allow itself to become automatically disengaged upon the reversal of the machine. The principal part of the process, however, is that involved in the breaking-machine, which can not be substituted by hand or other process, while the cleaning might be done in the ordinary way; in fact, when the flax is well retted the breaking is done so completely that a little handling cleans the fiber entirely from all show. The two machines may be worked separately. It is obvious that, the fiber being uninjured, there is a much larger output, and the heckle gives far more yield in line. About the importance of scutching there can be no question. Vast countries produce grasses and fibers which are of the highest value. The difficulty always has been to separate the fiber from the gummy exterior and from the inside pith or wood.

The Wallace Flax-cleaning Machine.—A flax-cleaning machine of novel design, devised by Mr. John O. Wallace, of Belfast, Ireland, is illustrated in Fig. 3. It is shown with the buf-

fer alongside, which is used for dislodging the woody matter. The machine is about 6 ft. 6 in. high by 4 ft. wide, and 5 ft. long over all; its working capacity being put at 1 cwt. of retted flax per hour. It consists of an upper feed-table, on which the flax straw is fed to three pairs of fluted rollers, which deliver the flax downward between five pairs of pinning-tools, alternating with six pairs of guide-rollers. The pinning-tools somewhat resemble hand-hackles, and are attached to two vertical frames, to which a horizontal to-and-fro motion is imparted, and the pins interlace as the two sides approach. The fibrous material is drawn downward by the rollers, which have an intermittent motion, and at each momentary pause the pricking-pins enter the material and are rapidly withdrawn from it. By degrees this fibrous descending curtain is delivered on to a sloping receiving-table at the bottom of the machine,

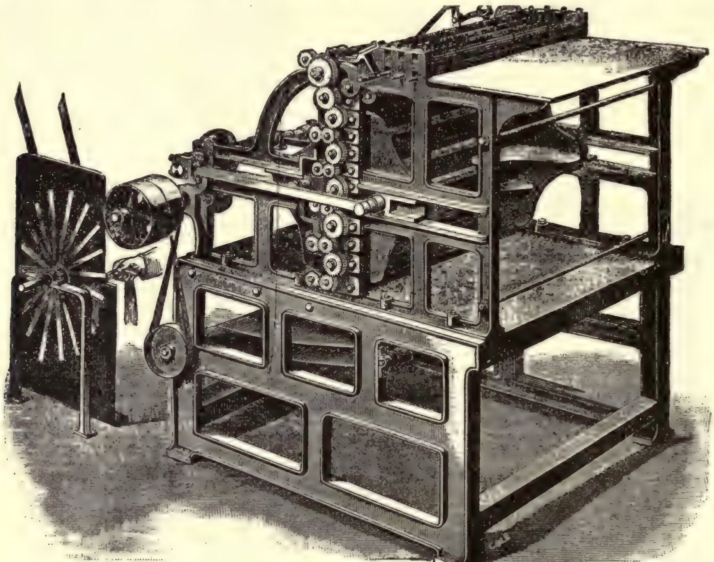


FIG. 3.—Wallace flax-cleaning machine.

over which table the woody substance has previously passed to a receiver in a crushed and semi-pulverized condition and perfectly free from fiber. Three attendants are required for one machine; but when large quantities of fiber have to be cleaned the same attendants are sufficient for three or four of the machines placed alongside each other. The attendants for one machine for flax are a boy or a girl to prepare straw in bundles, another to feed the straw to the machine, and a man to attend the buffer to clear off the broken woody portions. The two attendants who prepare the bundles and feed the straw can attend to two other machines, but each machine must have a man to buff or clean the flax. The driving power for each machine is two horse-power. It is claimed that this machine can be successfully used for cleaning ramie or rheea fiber.

Flight, Mechanical: see Aërial Navigation.

Flour-Bolter: see Milling-Machines, Grain.

Fly-Frame: see Cotton-Spinning Machines.

Flying-Machine: see Aërial Navigation.

Fodder-Cutter: see Ensilage-Machines.

Folder: see Book-Binding Machine and Presses, Printing.

Forced Draft: see Engines, Steam, Marine.

Forging: see Presses, Forging.

Fork, Hay: see Hay Carriers and Pickers.

Forming-Lathe: see Lathe, Metal-Working.

Friction of Engines: see Engines, Steam, Stationary Reciprocating.

Friezer: see Molding-Machines, Wood.

Fuel Consumption: see Furnaces, Blast, and Locomotives. **Fuel-Feeding Devices**: see Stokers, Mechanical. **Fuel, Gas**: see Gas-Producers. **Fuel, Petroleum**: see Engines, Steam, Stationary Reciprocating.

Furnace, Bullion Melting: see Mills, Silver. **Furnace, Glass-Making**: see Glass-Making. **Furnace, Open-Hearth**: see Steel, Manufacture of. **Furnace, Petroleum**: see Engines, Steam, Stationary Reciprocating.

FURNACES, BLAST. *Recent Development of American Blast-Furnaces.*—A paper read by Mr. James Gayley, superintendent of the Edgar Thomson Furnaces, Braddock, Pa., at the New York meeting of the Iron and Steel Institute, in September, 1890, gives a very full history of the development in blast-furnace practice since 1880. We extract from this paper as follows:

The development of blast-furnace practice in America in the direction of large yields is mainly the history of our working since the year 1880, as the advancement that has been made in the last decade is greater than that in the third of a century previous. A new era in the manufacture of pig-iron began in 1880 with the putting in blast of the Edgar Thomson furnaces. These furnaces at once leaped to the front as pig-iron producers, and have maintained that position—with but one brief interruption—ever since. As an example of the best work that was done in the ten years previous to that time, the Lucy furnace No. 2, of Carnegie, Phipps & Co., of Pittsburgh, may be noted. This furnace was built in 1877, of the following dimensions: Total height, 75 ft.; diameter of bosh, 20 ft.; diameter of hearth, 9 ft.; cubical capacity, 15,400 ft. The bell generally in use was 11 ft. in diameter. In the construction of this furnace, the noticeable features are a narrower hearth and a wider top than are now put in furnaces of the same cubical capacity; but at that time it was considered an excellent shape, and certainly did produce some excellent results. As early as 1878 this furnace had made a monthly output of 3,286 tons, on a coke consumption of 2,793 lbs. per ton of iron; and in one week shortly afterward made 821 tons. For the first 12 full months the output was 33,552 tons, on a coke consumption of 2,850 lbs. The amount of air blown was 16,000 cub. ft. per min., which entered the furnace through six 8-inch tuyeres; the temperature of the blast was 915°, and the pressure at tuyeres 5 lbs. The ore mixture yielded in the furnace 60 per cent iron. The work that was done at this furnace was unquestionably the best, all things considered, that had been accomplished prior to the starting of the Edgar Thomson furnaces.

Furnace "A" of the Edgar Thomson works was erected in 1879. The dimensions of this furnace are as follows: Height, 65 ft.; diameter of bosh, 13 ft.; diameter of hearth, 8 ft. 6 in.; cubical capacity, 6,396 ft. Six tuyeres, 4 in. in diameter, were used; these, projecting 7 in. inside the crucible, made the efficient diameter of hearth 7 ft. 4 in. The tuyeres were placed 5 ft. 6 in. above the hearth-line. The interior lines made very small angles with each other—so small, in fact, that the arc of a circle drawn from the top to the tuyeres will not deviate more than 2 in. from the lines as given. Particular attention was given to rounding the angles. The bosh was located about midway in the furnace, making the bosh-wall very steep. The batter of this wall was 1⅝ in. to the foot, which is equivalent to an angle of 84°. The furnace was lined throughout with small bricks. The stove equipment consisted of three Siemens-Cowper-Cochrane stoves, 15 ft. in diameter by 50 ft. in height. This furnace was "blown in" in January, 1880. The ore mixture yielded in the furnace 54·5 per cent iron. The output of the first full week was 442 tons, and reached 537 tons for the fourth week. The best week's output was 671 tons. The blast was heated to an average temperature of 1,050°, the utmost that the stoves would furnish; the pressure at the tuyeres was 6¼ lbs.

The volume of air forced into this furnace was 15,000 cub. ft. per min., or as much as was used elsewhere for furnaces of more than twice the capacity. The results obtained were surprising. Considering the cubic capacity of the furnace, the rate of driving was certainly excessive, and that the results on fuel were so low, as compared with the subsequent consumption on larger furnaces where the same practice was employed, is mainly due to the narrow furnace-stack. These fuel results were much lower than any obtained from the larger furnaces in the next five years.

The second furnace erected at these works had general dimensions as follows: Height, 80 ft.; diameter of bosh, 20 ft.; diameter of hearth, 11 ft.; cubical capacity, 17,868 cub. ft. The stock was distributed at the top by a double bell, in which the central cone remained stationary; while the outer conical ring, being lowered, cast the stock toward the wall and center of the furnace. One feature of this construction, differing from that of other furnaces then using coke for fuel, was the large hearth, providing more space for combustion. The in-walls of the hearth were straight, and the diameter 11 ft. There was an increased number of tuyeres, eight being used, and an increased elevation of tuyeres above the hearth-level, all of which were necessary for rapid driving and large yields. No American furnace up to that time had been constructed with so large a hearth as this one at the Edgar Thomson works. In another respect this furnace was well prepared by its designers for a high productive capacity, viz., in its equipment. Fire-brick stoves of the most approved type were erected. Substantially built blowing engines were provided, and they were rendered efficient by an ample supply of boilers—a point in which other furnaces were then sadly lacking. At the same time, all the flues and mains were constructed sufficiently large, and in the most substantial way. In fact, no furnace previously erected had been planned on such a liberal basis; consequently, large yields were to be expected. The furnace was put in blast in April, 1880. In the following month an output of 3,718 tons was made, and the next month showed 4,318 tons; thus fully justifying the claims of its designers by eclipsing all previous records. The weight of limestone was 25 per cent of the weight of the ore. An analysis of the cinder showed: silica, 32·31 per cent; alumina, 13·20 per cent.

The limestone contained a very small quantity of magnesia. The blast entered the furnace through eight bronze tuyeres of 5½ in. diameter, and was heated to a temperature of 1,100°. The silicon in the iron averaged about 2 per cent. The rapid wear of the furnace-walls, through the use of such a large volume of air, gradually increased the consumption of coke to over 3,000 lbs. per ton of iron. At the end of the first 12 full months the output was 48,179 tons, on an average coke consumption of 2,859 lbs. per ton of iron. The second year showed an average consumption of 3,200 lbs. of coke, with a decrease in yield. The furnace was blown out after a blast of two years and five months, having made a total product of 112,060 tons, on an average coke consumption of 3,149 lbs. per ton of iron. The results ob-

tained in this blast determined several important changes in construction. The crinoline structure was torn down and replaced by an iron jacket; the bosh-walls were protected so as to preserve as far as possible the original lines, and the hearth was surrounded with water-cooled plates. The double bell was also found to possess no special advantage, and was abandoned.

The practice of rapid driving, begun on furnace "A," and further developed on this one, had an important effect on the general practice of this country. The great outputs obtained from this furnace by the use of a large volume of air, was a matter of common knowledge; the practice of fast driving soon became the accepted one, and with our national ardor it was prosecuted enthusiastically. In every direction engines that had been running along for years at a methodical gait were oiled up and started off at a livelier pace; new boilers were added; the old iron hot-blast stoves, not supplying sufficient heat, were torn down and replaced by the more efficient fire-brick stoves. At many works rapid driving degenerated into excessive driving. True, the outputs increased; so also did the consumption of fuel, and that at a surprising rate, until it was thought well-nigh impossible to produce a ton of iron with 2,600 lbs. of coke. Although the practice of rapid driving has been much decried, yet in many ways it has resulted beneficially. It has brought in an equipment of hot-blast stoves, boilers, engines, etc., sufficient to accomplish a large amount of work without a constant strain on every part—a condition very rare prior to 1880; and it has also developed a construction of the furnace-stack by which larger outputs from a single lining can be obtained with less irregularity in the working.

Furnace "D" of the Edgar Thomson works, built in 1882, was of different construction from either of the preceding. It was constructed with special regard to the better protection of the brick-work of hearth and bosh. The general dimensions were as follows: Height, 80 ft.; diameter of bosh, 23 ft.; diameter of hearth, 11 ft. 6 in.; stock-line, 17 ft.; bell, 11 ft.; cubical capacity, 21,478 ft. The bosh is placed at about the center of the stack, making very steep walls. The hearth is also made wider by 6 in. than in furnaces previously described. The hearth-walls are surrounded by cast-iron plates with a coil inside for the circulation of water. Around the bottom of these plates is a gutter, through which waste water from the cooling plates flowed, affording better protection to the bottom of the hearth. Above this row of plates, at the tuyere breasts, is another circle of cooling plates, partially inserted in the brick-work. The walls of the bosh are incased in a jacket of wrought iron, ½ in. in thickness. This jacket is bolted on to the mantle. The bosh-walls inside the jacket were made but 22½ in. thick, so that the cooling effect of the air-currents on the jacket would prevent any very rapid wear of the brick-work. This furnace was put in blast in 1882. In the first 12 full months the output was 65,947 tons, on an average of 2,570 lbs. of coke per ton of iron, thus exceeding, by over 11,000 tons, the best output that had previously been obtained in the same time from any furnace at these works, and with a much smaller consumption of fuel. The record for the best month during this period was 6,131 tons, on a coke consumption of 2,387 lbs. per ton of iron. The amount of air blown was 27,000 cub. ft. per min., which was heated to an average temperature of 1,000°. The pressure of blast at the tuyeres varied between 9 and 10 lbs. After a blast of 17 months' duration this furnace was blown out, having made a total output of 90,317 tons, on an average coke consumption of 2,613 lbs. per ton of iron.

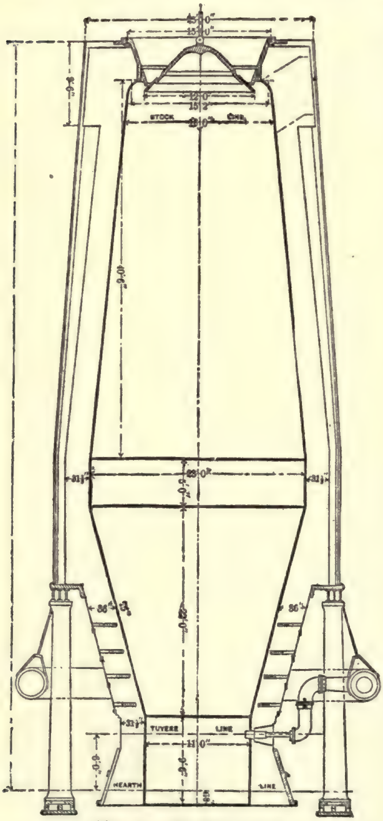


Fig. 1.—Blast-furnace.

Furnace "C" was reconstructed in 1885, with the following dimensions: Height, 80 ft.; diameter of bosh. 20 ft.; diameter of hearth, 10 ft.; diameter of stock-line, 16 ft. 3 in. The bosh-walls had an angle of 79°, and all the lines were joined by curves. The cubic capacity was 16,680 ft. In February, 1885, the furnace was "blown in." The volume of blast was rapidly increased until, in the following month, it reached 31,000 cub. ft. per min. The blast entered the furnace through eight tuyeres, 7 in. in diameter, and was heated to an average temperature of 1,200°. The pressure at the tuyeres was 8½ lbs. The average monthly output from March to August, inclusive, was 5,122 tons, on a coke consumption of 2,874 lbs. per ton of iron. Attempts were made later to increase the economy by reducing the volume of blast to 28,000 cub. ft. As a result the output increased to an average of 6,050 tons per month, on a coke consumption of 2,400 lbs. per ton of iron.

This furnace was again reconstructed in 1887, the hearth being widened to 11 ft. diameter, the bosh to 21 ft., and the stock-line reduced to 15 ft. The cubic capacity was increased to 17,230 ft. The furnace was "blown in" in March, 1887. On account of the brick-work in the bosh being very much worn, the furnace was blown out after a run of 2 years 7 months and 17 days—exclusive of the time the furnace was banked. The output for the blast was 203,050 tons, on an average coke consumption of 2,342 lbs. per ton of iron. The output for the first 12 full months was 72,554 tons, on a coke consumption of 2,230 lbs. For the second 12 months, during which no stoppage occurred, the output was 83,219 tons. The best output made in any one month was 7,680 tons. The furnace shown in Fig. 1 was built in 1886. The total height is 80 ft.; the diameter of hearth, 11 ft.; the diameter of bosh, 23 ft. The bell is 12 ft. in diameter, and the stock-line 16 ft. The cubic capacity is 19,800 ft. There are 7 tuyeres, each 6 in. in diameter. The furnace was started in October, 1886, and was in blast—exclusive of two stoppages—2 years 7 months and 10 days, and made in that time 224,795 tons of iron, on an average coke consumption of 2,317 lbs. The output for the first 12 full months was 88,940 tons on 2,150 lbs. of coke. The efficiency of the cooling plates on the bosh-walls was very marked in this case. The exterior brick-work was in as good condition at the end of the blast as at the beginning. The interior of the boshes had widened out 18 in., but with such uniformity that the greatest variation did not exceed 2 in. From the bosh-line to the top of the furnace the wear was much greater. The furnace was relined and blown in again in September, 1889. The construction was the same in every particular, except that the diameter of the bosh was reduced to 22 ft., and the stock-line to 15 ft. 6 in. The lining runs straight from bosh to stock-line. This change reduced the cubic capacity to 18,200 ft. The same number and size of tuyeres are used. The volume of air blown is 25,000 cub. ft. per min., a reduction of 2,000 cub. ft. from that used in previous blast. The best output for any one week is 2,462 tons. The temperature of blast averages 1,100° and the pressure 9½ lbs. The temperature of the escaping gases is 340°. Counting the time the furnace was running in the first blast, and up to the end of May, 1890, in the second blast, including also the time spent in relining, the period covered is 3 years and 5 months; and in that time this furnace has made an output of 301,205 tons, a record which is unparalleled. The ores used were from the Lake Superior region, and yield through the furnace 62 per cent of iron. The proportion of limestone carried was 28 per cent of the ore burden, and about 1,200 lbs. of cinder was made per ton of iron. The average analysis of the cinder is as follows: silica, 33 per cent; alumina, 13 per cent.

In the period covered by the last decade there are three steps in the development of American blast-furnace practice that might be mentioned: first, in 1880, the introduction of rapid driving, with its large outputs and high fuel consumption; second, in 1885, the production of an equally large amount of iron with a low fuel consumption, by slow driving; and third, in 1890, the production of nearly double that quantity of iron, on a low fuel consumption, through rapid driving. An abstract of the results given by Mr. Gayley is shown in the following table:

Blast-Furnace Practice—Abstract of Results.

Designation of Furnace.	Year in which furnace commenced the blast.	Cubic capacity.	Volume of air per minute.	Total output from blast.	In First Twelve Full Months.			
					Output.	Average daily output.	Average coke consumption.	Capacity for one ton of iron per day.
		Cub. ft.	Cub. ft.	Tons.	Tons.	Tons.	Lbs.	Cub. ft.
Isabella	1876	15,000	......	117,575	28,000	76	3,000	197
Lucy No. 2	1878	15,400	16,000	92,128	33,552	91	2,850	169
Edgar Thomson, A	1880	6,396	15,000	......	......	71 *	2,400	90
" " B	1880	17,868	30,000	112,090	48,179	132	2,859	135
" " D	1882	21,478	27,000	90,317	65,947	180	2,570	119
" " C	1885	16,680	31,000 †	118,000	64,998	178	2,677	90
" " D	1885	18,950	22,000	150,377	74,475	204	2,250	92
" " C	1887	17,230	24,000	203,050	72,554 ‡	198	2,230	87
" " F	1886	19,800	27,000	224,795	88,940	244	2,150	81
" " F	1889	18,200	25,000	......	113,000 §	310	1,920	59

* Estimated. † After running 9 months the volume of air was reduced to 28,000 cub. ft.

‡ The second 12 months, by reason of a continuous blast, show an output of 83,219 tons on 2,396 lbs. of coke. § Estimated from record made to date.

Note.—On the completion of the 12 months in blast, the record for furnace F, blast of 1889, shows an output of 413,526 tons, and an average coke consumption of 1,892 lbs.

A Modern Blast-Furnace Plant.—One of the most recent complete blast-furnace plants is that of four furnaces built in 1890 at the South Chicago Works of the Illinois Steel Co., and known as Nos. 5, 6, 7, and 8. The furnaces are built in a line extending east and west, with the cast-houses branching off to the south, and they may be considered as constituting two separate plants of two furnaces each. The individuals of each pair are side by side, and 126 ft. from center to center. Each furnace is 80 ft. high. Nos. 5 and 6 are similarly constructed, each having a bosh of 22 ft., hearth of 12½ ft., and a stock-line of 16 ft. In No. 7 the bosh is 20 ft., but in other respects the lines are the same as in Nos. 5 and 6. No. 8 is considered, so far as the lines are concerned, as quite a radical change from the other three, for its bosh is only 19½ ft., hearth 13 ft., and stock-line 13½ ft., thus showing a tendency to spread out at the hearth and contract in the upper portions. Nos. 5 and 6 are built with five and No. 7 with nine rows of bosh-plates. Each furnace is supported by eight columns 20 ft.

high, and is re-enforced at the hearth with a steel jacket 1½ in. thick by 7 ft. high. Nos. 5 and 6 are furnished with 7-in. bronze tuyeres that extend into the furnace 1 ft. No. 7 has a telescope arrangement for the tuyere, water-jacketed breast, and water-block, all the parts being made of bronze, and so easily adjusted that there is very little delay in replacing them when necessary to make repairs. Each furnace has four Massick & Crooke hot-blast stoves, 22 ft. in diameter and 70 ft. high. They are arranged in a line just north of and parallel to the line of furnaces. Two of each of the four stoves are "on wind" and two "on gas," the change being made every half-hour in such a manner that there is a fresh stove "on wind" all the time. These stoves at present maintain an average temperature of only 1,250° F. to the hot-blast. Directly north of the line of stoves is the stock-yard. Here the coke, ores, and flux are all handled. The coke is unloaded as needed from three rows of trestles placed parallel to the line of stoves, and back of these are three more trestles, from which the flux and ore can be unloaded when necessary. Usually the ore is unloaded directly from the boats on to the docks and taken to the hoists in barrows. It is handled at the docks by 13 Brown hoisting and conveying machines, having an aggregate capacity of 8,000 tons per 24 hours. A double hoist-tower and hoist-engine are placed between each second and third stove. They are the ordinary crane-hoists, and each cage carries two barrows. The harbor was made by dredging, and is 2,600 ft. long by 150 ft. wide, with an average depth of 20 ft.

West of the furnaces are the boiler and engine houses. The former is 87 ft. by 291 ft., and has 40 horizontal tubular boilers 6 ft. by 20 ft. The water used in these boilers and around the furnaces is pumped from the lake. The engine-house is 57 ft. by 250 ft. It is equipped with 10 Southwark blowing-engines, having steam-cylinders 40 in. by 60 in., and 6 cylinders 89 in. by 60 in. The valves are of the regular Porter-Allen link-motion. Two of these engines are held in reserve for contingencies, either one of which can be turned on to any furnace. In the pump-house are 8 compound duplex Worthington pumps, with steam cylinders 29 in. and 18½ in., water-cylinders 18 in. in diameter, and a stroke of 21 in. West of the engine-house is the main water-tank, which is 17 ft. deep and 40 ft. in diameter, and is supplied by means of three centrifugal pumps placed at the lake. In addition to the main tank there are four of smaller capacity, so placed as to be convenient to the furnaces which they are to supply.

The ores smelted by this plant are the hematites of the Lake Superior region. They may be roughly classified as hard and soft ores. In making the mixture, about 15 per cent of the former to 85 per cent of the latter is mixed with a dolomite for the flux, and coke for the fuel. The richest ore will analyze about 62 per cent of Fe (iron), and the poorest will not fall below 50 per cent of Fe. They show on an average about 1·30 per cent of SiO_2 (silica), ·021 per cent of S (sulphur), and ·09 per cent of P (phosphorus). The dolomite contains 1 per cent of SiO_2, 1 per cent of Al_2O_3 (alumina), 53 per cent of $CaCO_3$, and 45 per cent of $MgCo_3$ (magnesium carbonate).

These furnaces are built to make 300 tons of pig-iron each per day. The iron is run from the furnaces into ladles of 12 tons' capacity each, and taken by locomotives to the steel-mill in the liquid state. The cinder is carried off by Weimer cinder-buckets and dumped into the lake before it has time to harden.

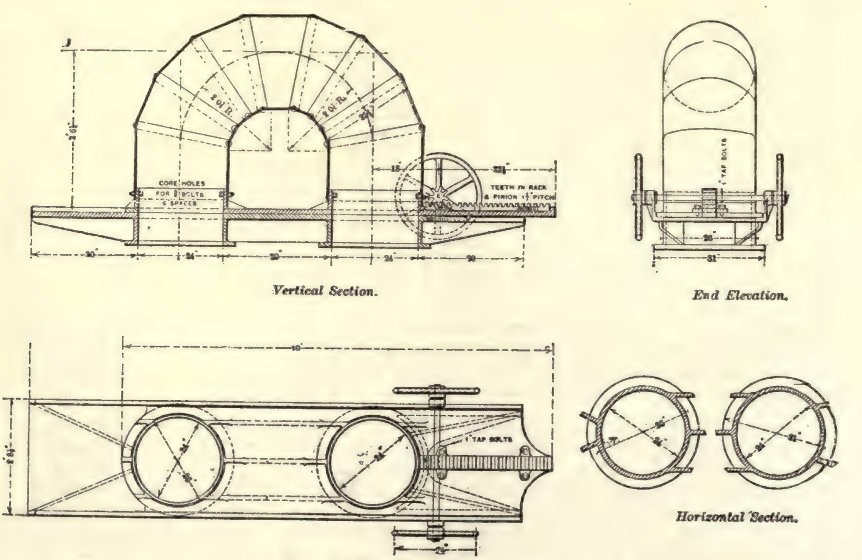


FIG. 2.—The Kennedy furnace.

The Kennedy Gas-regulating and Cut-off Valve.—Hugh Kennedy, of Sharpsburg, Pa., manager of the Isabella furnaces, has designed a gas-regulating and cut-off valve which has been found a very convenient arrangement, since one furnace may be cut off without stopping

the others. In a furnace-plant which comprises several furnaces, it has been found conducive to the regularity of work to cause the gas from all the furnaces to discharge into one main flue, from which the boilers and stoves are supplied. Valves have been placed in the main flue, in order to be able to cut it off from an individual furnace, so that the men can get access to parts where the presence of gas would be dangerous. Owing to the large size of the flues and the necessarily large dimensions of the valves, it has been found difficult to shut off the gas perfectly. Mr. Kennedy, instead of making the flue continuous, divides it by cross-walls into parts corresponding to the number of furnaces, and connects the adjacent parts with each other by removable pipe-connections. The construction of the device is shown in Fig. 2. The U-shaped pipe shown is attached to a plate-casting having holes registering with the openings of the pipe. This plate is set in another plate, and is provided with a rack and pinion, as shown, by which it may be moved longitudinally. The whole is placed on top of the main flue, the partition-wall in which is located between the two openings referred to. A shifting of the pipe and the plate to which it is attached enables the operator to cut off completely the connection between the two adjoining parts of the main flue.

FURNACES, GAS. *Classification.*—The different kinds of furnaces for burning gaseous fuel are thus classified in a paper in the *Proc. of the Inst. of Mech. Eng.*, January, 1891:

Gas-furnaces may properly be divided into four classes, namely: (*a*) with reversing regeneration; (*b*) with continuous regeneration; (*c*) non-regenerative; and (*d*) with blow-pipe or forced blast.

(*a*) Furnaces with reversing regeneration are of several different kinds:

1. The ordinary Siemens furnace, in which both gas and air are heated before admission to the interior of the furnace, by being passed through the well-known arrangement of brick chambers filled with checker-work or loosely piled bricks.

2. The Batho or Hilton furnace, in which the regenerative chambers, instead of being partly or entirely underground, are incased in cylindrical wrought-iron vessels erected upon the ground-level.

3. Furnaces in which the air only is regenerated by being passed through chambers, the gas being admitted direct from the flues by which it arrives from the producers. In these furnaces the whole of the escaping gases or waste heat has to pass through one of the two air-chambers on its way to the chimney.

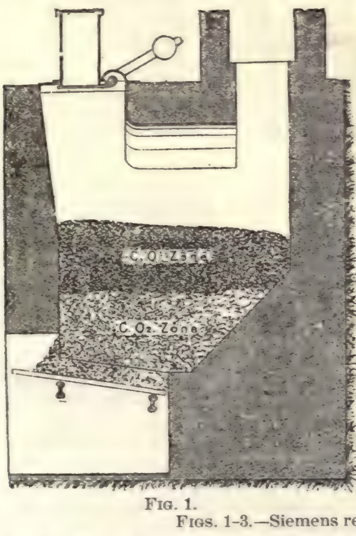
4. The furnace recently described by Mr. Head (*Iron and Steel Institute Journal*, 1889), in which a portion of the waste heat is taken back to the gas-producer.

5. The various regenerative blast-furnace stoves of the Cowper, Whitwell, and other kinds.

(*b*) In furnaces with continuous regeneration, the air, before admission to the interior of the furnace, is heated in flues or pipes by radiation or conduction from the bottom of the furnace, and through thin walls which separate the air-flues from the flues that carry the spent gases or waste heat to the chimney.

(*c*) In non-regenerative furnaces the air is admitted to the interior of the furnace at its natural or atmospheric temperature.

(*d*) Blow-pipe or forced-blast furnaces are of two kinds: First, those in which the air is supplied at its natural or atmospheric temperature by a fan or blower; second, those in which the air so supplied is heated by the spent gases or waste heat from the furnace, by being passed either through coils or stacks of pipes, or else through brick tubes or flues, as in the case of the Radcliffe furnace and others.



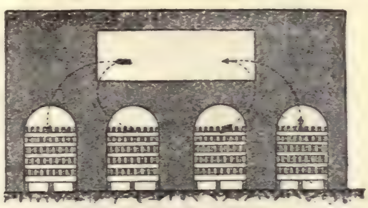


FIG. 2.

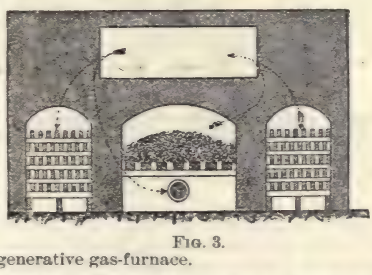


FIG. 1. FIG. 3.

FIGS. 1-3.—Siemens regenerative gas-furnace.

A New Siemens Regenerative Gas-Furnace.—Messrs. John Head and P. Pouff, in a paper before the Iron and Steel Institute, read in 1889, describe a novel form of regenerative fur-

nace. We extract from their paper as follows: In the new Siemens furnace the gaseous products of combustion from the heating-chamber of the furnace are delivered under the grate of the producer, these gases consisting of intensely hot carbonic acid, water in the gaseous state, and nitrogen. The economy of fuel resulting from the conversion of carbonic acid into carbonic oxide is diagrammatically illustrated by means of the sketch (Fig. 1) of a gas-producer. Assuming that the producer contains only coke in the incandescent state, this coke, if fed with oxygen, will produce carbonic acid in the lower zone, which will be converted into carbonic oxide in the upper zone; but if fed with hot carbonic acid instead of oxygen, one half of the fuel, comprising the lower zone, may be dispensed with, and an economy in weight of fuel to the same extent will be realized. In the new Siemens furnace the waste gases are directed partly through an air-regenerator and partly under the grate of the producer, there to be reconverted into combustible gases, and to do the work of distilling hydro-carbons from the coal; in fact, the gas-producer in this case absorbs or utilizes the heat formerly deposited in the gas-regenerators of furnaces, and in doing this transforms spent gases into combustible gases.

For the propulsion of the gases through the converter a steam-blast is employed. This steam is superheated by the waste gases from the furnace, and, mixing with them, forms a very hot blast under the grate. The diagrams (Figs. 2 and 3) show the relation which exists between the ordinary and the new type of Siemens furnace. The function in both is the same. In the first case the waste gases are partly directed through two regenerators, while in the second case the waste gases are partly directed through an air-regenerator and partly through a converter-producer. In both cases the waste heat from the furnace is entirely

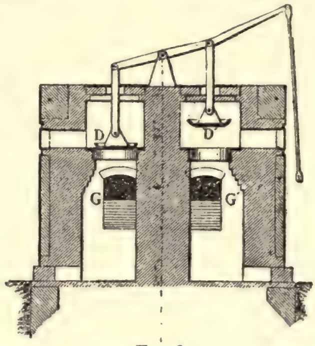


FIG. 6.

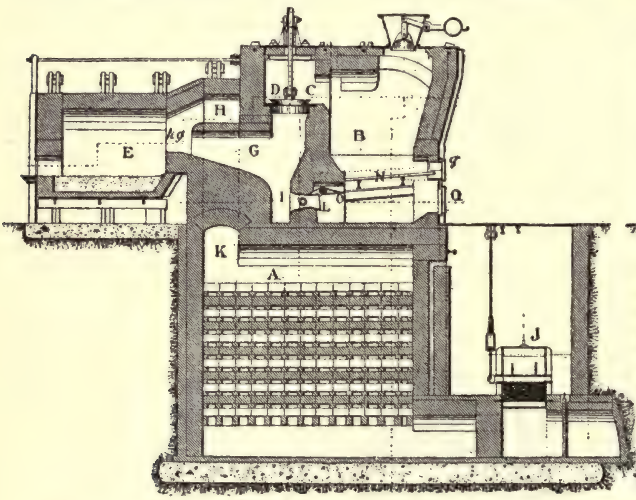


FIG. 4.

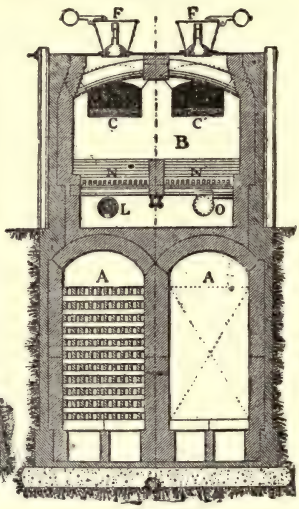


FIG. 7.

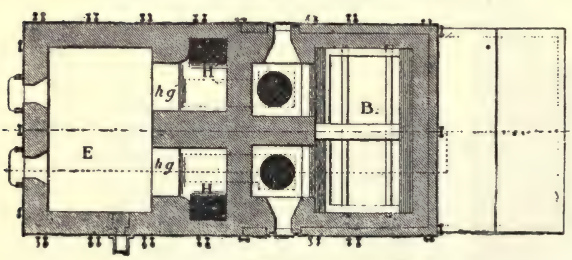


FIG. 5.

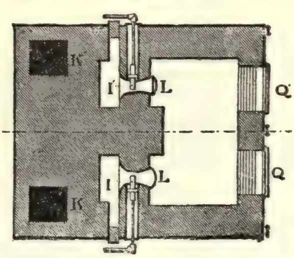


FIG. 8.

FIGS. 4–8.—Siemens regenerative gas-furnace.

utilized, and the gas and air reach the furnace in an intensely heated condition. In both cases, again, there is a reversal in the direction of the flame in the furnace, which insures uniform heating of the furnace-chamber and the materials contained in it.

This furnace may be constructed in various forms, that shown in Figs. 4, 5, 6, 7, and 8 having been used with success for heating and welding iron. It is a radiation-furnace, heated

by means of a horseshoe-flame; this form of flame offers advantages in this as in ordinary regenerative gas-furnaces, but its adoption is not obligatory, as the flame may be made to traverse the heating-chamber from end to end in the usual manner. The same letters indicate the same parts in all the figures. $A\ A^1$ are reversible regenerators for air, on the top of which is built the gas-producer or converter B, of which $F\ F^1$ are the charging-hoppers and $N\ N^1$ the grates. The heating-chamber E adjoins the producer resting on the ground, or in some cases a pit may be provided below it. $C\ C^1$ are the flues leading the combustible gas to the furnace-chamber E, the passage of the gas in these flues being controlled by the valves $D\ D^1$ at the two ends of a rocking beam, so that the outlets are opened and shut alternately to convey the gas to one or other of the ports $G\ G^1$ of the heating-chamber E. $H\ H^1$ are the air-ports of the heating-chamber, communicating through the flues $K\ K^1$ with the regenerators $A\ A^1$. $I\ I^1$ are steam-jets placed in the return-flues $L\ L^1$ for directing a portion of the waste products of combustion to the grates of the converter. J is the valve for reversing the direction of the air flowing into the furnace, and of the products of combustion through the regenerators to the chimney-flue. $O\ O^1$ are hinged caps for alternately admitting and shutting off the products of combustion from the heating-chamber to the converter. These caps are worked automatically by means of connections attached to the rocking beam, the same movement which closes D opening O^1, and that which closes D^1 opening O; $Q\ q$ are doors for giving access to the grates of the converter for clearing them.

The *modus operandi* of the furnace is as follows: Gas from the converter B passes through the flue C^1 and the valve D^1 to the gas-port G^1, and into the combustion-chamber $h^1\ g^1$. Air for combustion passes through the regenerator A^1, the air-flue K^1, and the air-port H^1 into the combustion-chamber, where it meets the gas from the converter, and combustion ensues. The horseshoe-flame sweeps round the heating-chamber E, the products of combustion passing away by the second combustion-chamber $h\ g$, and going partly through the regenerator A and reversing-valve J into the chimney-flue, and partly down the flue G, whence they are drawn by means of the steam-jet I through the capped inlet L under the grates of the producer B, there to be converted into combustible gases. From time to time the direction of the flame in the furnace is reversed by manipulating the rocking beam, carrying the valves $D\ D^1$ and the reversing-valve J in the usual manner of working regenerative gas-furnaces. An auxiliary steam-jet is provided for the purpose of supplying atmospheric air to start the producer when the furnace is first heated up.

The following advantages are claimed for the new furnace as compared with solid fuel furnaces used for heating and welding iron, viz.: A saving in fuel, amounting to, say, two thirds in weight, after allowing for raising steam in separate boilers, this saving being fully equal to 5 cwt. of coal per ton of iron heated. A reduction in the waste of iron equal to 5 per cent upon the weight of metal heated. A saving in labor and repairs which will probably compensate for the extra cost of the new furnace.

The Pettibone-Loomis Open-Hearth Furnace (Fig. 9).—This furnace is designed for all kinds of open-hearth work using manufactured or natural gas, and is particularly effective with water-gas for very high heats. Gas and air are used under uniform pressure; the former being conducted through the pipes $a\ a'\ a''$ to the burners E, the air passing through the pipes J, where it is heated by the waste products of the furnace, and thence through the pipes $b\ b'$ to the burners, where the two are thoroughly mixed, delivering a flame of great intensity tangentially into a round furnace. After circulating over the bath the products are taken out near the top of the hearth through the passage F and air-heater C to the stack. The burners are movable, and the flame can be directed on to the bath, or horizontally, as desired. The claims for this furnace are: 1. Low cost and durability. 2. Thorough and active combustion of gas with application of heat to metal by radiation or contact. 3. Character, intensity, and volume of flame under control of the operator. 4. Economy of fuel and certain results.

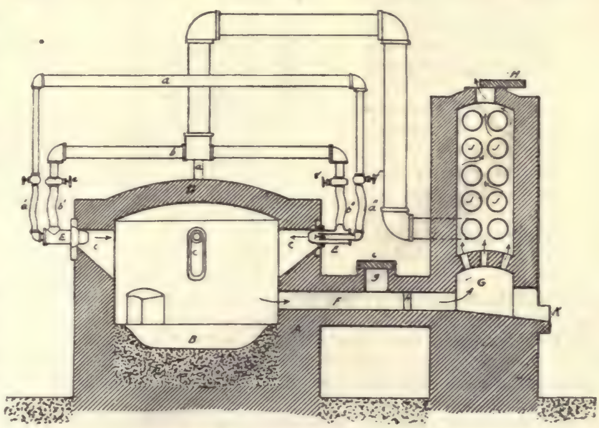


FIG. 9.—Open-hearth furnace.

Gas-Furnace for Melting Metals.—Fig. 10 shows one of many styles of furnace made by the American Gas-Furnace Co. of New York. This style of furnace is in use for gold, silver, copper, and brass, as also for making tests and smaller melts of iron, steel, glass, etc.

The combustion-chamber consists of the bottom A, and the cylinder B, both firmly secured to the distributing-ring C. The burners D penetrate the "bottom" lining A. The bottom is held in position by the iron platform L. The cylinder B is secured to the distributing-ring C by the hinged bolts O. The cover H is hinged to the shaft K, so as to lift clear of the

furnace-top when swung to either side. The "feed-hole" in cover *H* is sufficiently large to give free access to the crucible without removing the cover, thus confining the heat while feeding the crucible. The small cover *I* closes the feed-hole. The crucible stands upon a conical fire-brick support. By means of outlets for the products of combustion, both at the bottom and top of the furnace, the greater heat can (in a measure) be made to act either upon the bottom or top of the crucible. When the vent on top is tightly closed, the greatest heat will be below, while the partial opening of the cover *I* will draw it upward. Air under pressure is supplied through the pipe *F*. The consumption of gas is according to the quality of the gas and the temperature required. The furnace shown in the cut will require from 200 to 250 cub. ft. of gas per hour, and melt 40 lbs. of copper in 30 min.

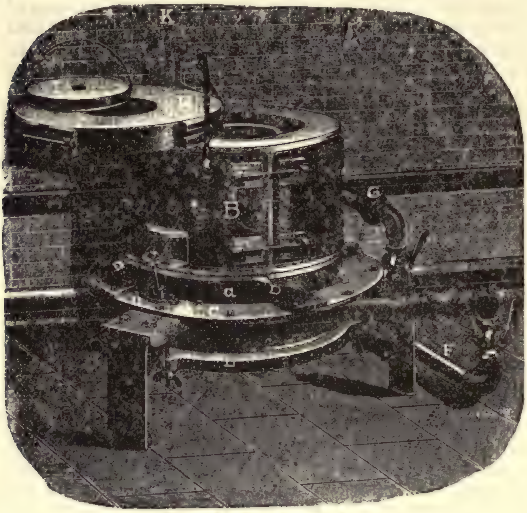


FIG. 10.—Gas-furnace.

The Howe Experimental Regenerative Gas-Furnace. — Mr. Henry M. Howe, in a paper read before the American Institute of Mining Engineers, February, 1890, describes a furnace used by him in experiments on the thermal properties of slags. It was necessary to have command of a very high temperature, at least 1,400° C. (2,552° F.), and to make such dispositions that the platinum-ball used for a pyrometer, and the silicate or silicates experimented on, should be at approximately the same temperature at the moment of withdrawing the former. The regenerative gas-furnace shown in section in Fig. 11 is made with two regenerators, loosely filled with lumps of fire-brick. Through one of the regenerators at a time part of the air used for combustion is brought under pressure from a blower, the products of combustion passing out through the other regenerator and to waste. Common illuminating gas is used for fuel, and is brought in alternately through pipes. With this gas is mixed a considerable quantity of air, brought alternately by the pipes *H H'*. It was found necessary to thus mix quite a large volume of air with the gas before admitting it into the furnace, to prevent rapid decomposition of the gas with deposition of carbon. At intervals, usually of 5 min. each, the furnace was reversed by means of common three-way gas-cocks. Although only part of the air and none of the gas was pre-heated in this furnace, a temperature of 1,400° C. was reached in it; the hearth of the furnace was made of a molded brick, with depressions for five platinum crucibles *N N'*, and for the platinum-ball *M*. Crucibles and balls were introduced and removed through the doorway *L*, closed with a tightly fitting molded wedge-brick.

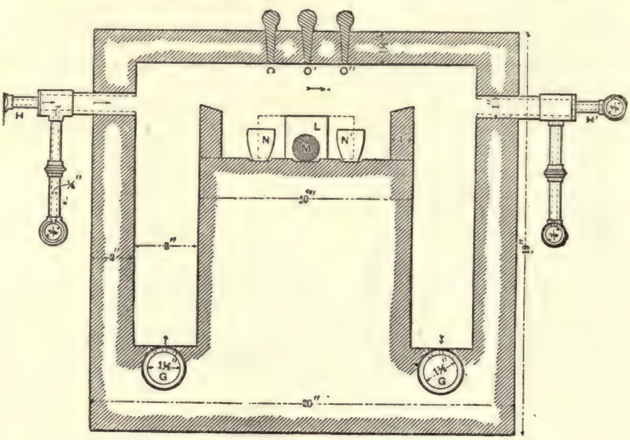


FIG. 11.—Howe gas-furnace.

Refractory Materials for Gas-Furnaces.—Clay fire-brick, of nearly pure silicate of alumina, free from iron, is usually employed in ordinary heating-furnaces, but for the intense heat required in steel-melting furnaces a more durable material is needed. For the roofs of such furnaces silica brick, composed of nearly pure quartz, with from 1 to 2 per cent of other materials, chiefly lime and alumina to give binding quality, are used. For the basic open-hearth furnace there is required a material which will not be acted upon by the basic slag, and at the same time will withstand the highest temperatures. Such a material is magnesite brick, made from carbonate of magnesia, and containing when burned about 90 per cent of magnesia and 10 per cent of silica and oxides of alumina and iron.

FURNACES, PUDDLING AND HEATING. *The James Puddling-Furnace* is shown in Fig. 1. It has a hollow fire-bridge *C*, with a transverse flue *K*, from which a number of orifices, *c*, lead upward. The air is preheated in the flue *P*, which connects, as shown, with the space *E* in the fire-bridge under the fuel-chamber *A*, and the grate-bars *a* is an air-chamber *D*, formed by a tight box *d*. Leading into this air-chamber are a number of air-pipes *e*, into the bell-shaped mouth of which the nozzles of steam-pipes *f* are projected, so that the steam draws in air. Above the bridge is a cold-air flue *g*, connected with a number of openings with the furnace above the fire-bridge. It is provided with a valve to regulate the admittance of cold air when required. While in the ordinary type of puddling-furnaces the consumption of good Pittsburgh coal was 2,200 lbs. at the Arethusa Works, Newcastle, Pa., with the James modifications the consumption was but 1,800 lbs. with the same coal. Similar results were attained in the heating-furnaces of the plate-mill.

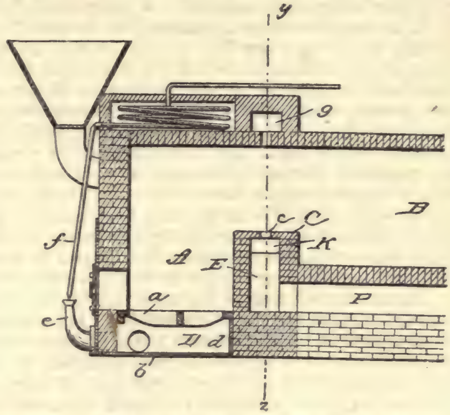


Fig. 1.—James puddling-furnace.

The Stubblebine Heating-Furnace is shown in Figs. 2, 3, and 4. It has been introduced in the Bethlehem and Catasauqua (Pa.) rolling-mills. The gases from the furnace are split when issuing from the reverberatory chamber into three parts, the one passing through the up-take through the stack. On either side thereof two flues lead to two heating-chambers, in which are placed coils of pipe through which air is blown and in which it is

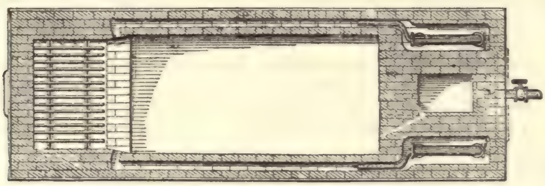


Fig. 2.

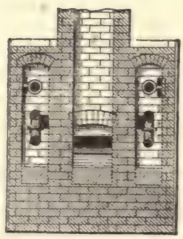


Fig. 4.

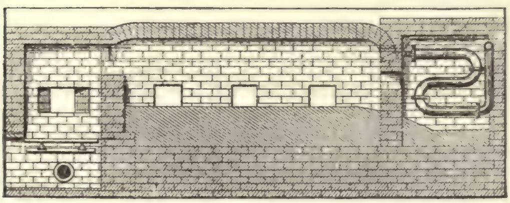


Fig. 3.

Fig. 2-4.—Stubblebine furnace.

preheated. The heated air issues from two nozzles into mixing flues in the side walls of the furnace. In this manner the gas in the preheating chambers is drawn by the suction created into the mixing flues, which discharge them into the flame at the fire-bridge. The furnace works well on billets, and on large or small fagots. It heats quickly, and the flame is under such control that the waste by oxidation is very low.

FURNACES, ROASTING. Roasting-furnaces are either oxidizing or chloridizing, according as the purpose for which they are used is to convert the metals in the ores treated to oxides or chlorides. There are six kinds of roasting-furnaces in common use, viz.: kilns, muffle-furnaces, reverberatory furnaces (Fortschaufelungsofen), shaft-furnaces, mechanical hearth-furnaces, and cylindrical furnaces.

Reverberatory furnaces, which are most commonly used for calcining fine ores, consist of a long brick hearth, with a low roof, and a series of small doors on one or both sides. At one end of the hearth is a fire-box, and at the other a flue connecting with the chimney, a dust-chamber usually being interposed. The fine ore to be roasted is fed in through a hole in the roof at the flue end, and is gradually worked forward toward the fire-box end by men using long rabbles through the doors in the sides. The flames from the fire-box draw over the ore toward the flue, the low roof throwing them down on to the ore. The roasted ore is pulled out of the furnace through the doors next to the fire-box. Reverberatory furnaces are frequently built with two hearths, and sometimes three or four, placed one above the other, the flames drawing successively through each. The object of this arrangement is obviously to

increase the length of the hearth, and its utility is determined by the character of the ore to be roasted. The length of the hearth, according to Dr. E. D. Peters, Jr., is limited chiefly by the capacity of the ore to generate heat during its oxidation, the immediate influence of the fireplace being seldom capable of maintaining the requisite temperature upon a hearth over 16 ft. in length without resorting to the use of a forced blast, or of a draft so powerful as greatly to increase the loss in dust, as well as the consumption of fuel. An ore carrying less than 10 per cent sulphur will not furnish sufficient heat to warrant the addition of a second hearth to the first 16 ft.; an increase to 15 per cent will be sufficient, however, to heat a second hearth, while a 20 per cent sulphur-ore will work rapidly in a three-hearth furnace. The addition of a fourth hearth is rendered justifiable by the increase of the average sulphur contents to 25 per cent. As there seems to be almost no limit to the extent of surface over which the requisite temperature may be obtained in the calcination of highly sulphureted ores, much longer furnaces have been used, 120 ft. being the extreme inside limit. The width of the furnace should be as great as is compatible for convenient manipulation. Experience has shown 16 ft., inside measurement, to be the extreme limit. The capacity of a large reverberatory furnace varies from 6 to 16 tons per 24 hours, depending upon the character of the ore. The cost of calcining ranges from $1.25 per ton upward.

In the shaft-furnaces the material to be roasted is allowed to fall as a shower of dust through a shaft that is traversed from bottom to top by the flames from a lateral fireplace. In one class of shaft-furnaces the dust falls freely; in others there are obstacles in the way. The well-known Stetefeldt furnace is the most successful furnace of the open-shaft class, and the Gerstenhöfer and Hasenclever may be taken as types of the latter class. The Stetefeldt furnace is generally used for chloridizing roasting, but experiments have shown that it may be also an efficient oxidizing furnace, although it has not yet come into practical use for that purpose. The capacity of the Stetefeldt furnace, according to Mr. C. A. Stetefeldt, is from 35 to 80 tons per 24 hours. If the ore is so base that 75 or 80 per cent of it is in the form of sulphurets, 35 tons is the maximum limit for really good work. In most cases, however, where the ores contain only a moderate percentage of sulphurets, a large furnace will easily handle from 60 to 80 tons per 24 hours, but the latter figure is probably the economical limit.

The mechanical hearth-furnaces are hearth-furnaces with mechanical devices for raking or stirring the charge. They have circular hearths, rotating under fixed rakes; or fixed hearths, either circular or rectangular, and movable rakes.

The cylindrical roasting-furnaces are cast-iron cylinders, lined with fire-brick, through which the flame draws from a stationary fire-box at one end to the flue and dust-chamber at the other. The charge is stirred, so that all its parts are subjected to the action of the flame, by the rotation of the cylinder. The Brückner, Douglas, White, and Howell-White furnaces are types of this class.

The cost of roasting varies with the character of the ore, the kind of furnace, and the cost of fuel and labor. The lead-smelters at Denver, Col., roast ore in reverberatory furnaces at an average cost of $2 per ton. With a mechanical hearth-furnace at the Haile mine, North Carolina, pyrites concentrates are roasted preparatory to chlorination at a cost of $2.62½ per ton. Under favorable circumstances, pyrites concentrates have been roasted in the West, even where labor and fuel is high, for as low as $1 per ton.

Kilns.—The ordinary type of roasting-kiln is too well known to require description. They are, obviously, used in roasting coarsely broken ores only. A modification of the common kiln which is in general use for calcining iron-ores may be termed shaft-kilns, working upon the same principle as shaft-furnaces—i. e., the ore being desulphurized while descending through a rising current of flames, but, as in the kilns, the ore is in coarse lumps and is made to descend slowly rather than in a shower of fine ore as in the shaft-furnaces. The Gjers kiln and the Davis-Colby roaster are furnaces of this class.

The Gjers kiln, extensively used in calcining iron-ores, is a circular shaft-furnace built of fire-brick cased with malleable iron plates. The bottom of the brick-work rests in a cast-iron ring, and the whole is supported by cast-iron pillars about 2½ ft. high, leaving a clear space between the bottom of the kiln and the floor. The latter is covered by iron plates, in the center of which is fixed a cast-iron cone 8 ft. in diameter at the base and 8 ft. high, extending up within the shaft. Around the lowest tier of plates incasing the kiln are openings which are usually closed by doors, but which serve for admission of air or tools in case the ore becomes sintered. The ore, mixed with a proper proportion of coal, is fed into the furnace at the top, which is surrounded by a gallery for the workmen. The roasted ore descending is caused by the interior cone to pass outward at the bottom of the furnace. These furnaces are usually 33 ft. in height; at the base they are 18 ft. in diameter, widening to 24 ft. 10 ft. higher up. The upper part of the kiln is cylindrical, and 24 ft. in diameter. A kiln of this size has a capacity of about 8,000 cu. ft., and calcines about 115 tons of iron-ore per 24 hours, the consumption of coal amounting to 1 ton for 25 tons of ore.

The Davis-Colby Ore-Roaster, which is also much used for desulphurizing iron-ores, consists of a circular hollow shaft with walls about 2 ft. in thickness, in which are located fire arches fed with gas, which gas may be taken from any source—gas-producers, natural wells, or the waste-pipes of blast-furnaces. The gas-mains enter flues built in the masonry directly over the fire arches, and the gas is drawn through openings left in the top or bottom into the arches, where it takes air and is consumed—the resulting flames being drawn directly into and through the ore. In the center of the kiln there is a smaller hollow shaft, starting from the bottom and extending up through the entire portion of the kiln and terminating in the draft-stack—

being, in fact, the draft-stack itself. In the walls of this central shaft, and opposite the fire arches, are a series of openings through which the products of combustion are drawn directly into the stack and discharged so that the heat from the burning gases is drawn across a narrow body of ore instead of up through the overlying mass, and the liberated sulphur allowed to pass off directly. There may be any number of rows of fire arches, and below each of these is a row of openings for admission of air.

The latest form of these roasters is 30 ft. in height, and 17 ft. diameter at bottom and 14 ft. at top, with the central flue terminating in a draft-stack 48 in. in diameter. The ore is dumped into the top of the kiln and occupies the annular space between the two walls. Descending by gravity, it first meets the current of gas from the upper set of fire arches and gets a preliminary drying and warming. Passing thence before the next and lower arches it gradually reaches a red and even white heat, every part of the ore rolling and turning over in its passage, and being subjected while highly heated to drafts of air, the liberated sulphur passing directly off into the central stack. The annular space, being 14 in. at the top and gradually increasing to 29 in. at the bottom, gives opportunity for constant moving of the ore and decreases the chances of its adhering to the walls. The roasted ore is drawn through chutes directly into bins, barrows, or conveyers. The discharge of ore is regulated by drawing from the chutes, and the heat by varying the amount of gas. The furnaces vary in capacity, according to the ore. At the Croton mines, Brewster, N. Y., from 200 to 300 tons per day are said to be run through each furnace. Mr. W. H. Hoffman (*Trans. A. I. M. E.*, October, 1891) thus describes the practice there: "A series of experiments was made to determine the best size for economical roasting (the ore containing 2 per cent sulphur), and at the end of three months a size that would pass through a 2¾-in. ring was adopted as giving the most rapid work for the quantity of fuel consumed. Crude Lima-oil is used for roasting, the furnaces being remodeled for this purpose. Through experiments conducted by our general foreman, Mr. T. Blass, we found the average consumption of fuel-oil to be 3·75 gals.; but by enlarging the combustion chambers we have reduced this amount to a little over 3·6 gals. per ton of raw ore. The cost of the oil is 2¼ cents per gal., making a fuel cost of 8½ cents per ton of raw ore. The labor of filling and discharging amounts to only 3 cents per ton, as this work is largely automatic. The average temperature is 1250° F., and the ore is roasted down to about 0·5 per cent sulphur."

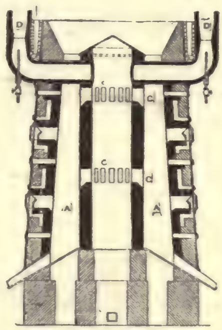


FIG 1.—Roasting-furnace.

A modification of this type is shown in Fig. 1, in which the draft-stack is cut off and surmounted by a bell, the draft being downward and outward at the bottom of the kiln. In this case the ore is dropped from self-dumping cars directly on to the bell which distributes the charge, and falling by gravity is drawn directly into the furnace barrows, thus avoiding all handling of ore from the mine to the furnace-top.

MECHANICAL HEARTH-FURNACES.—*The Rotary-Pan Furnace* (Fig. 2) used at the Haile mine, North Carolina, for roasting fine pyrites for chlorination, is a combination of the reverberatory furnace with the mechanical hearth-furnace. It is a reverberatory furnace with step-hearths and a circular rotating hearth at the fire-box end. The charge is fed at the flue end and gradually worked forward by hand to the circular hearth, where the roasting is finished.

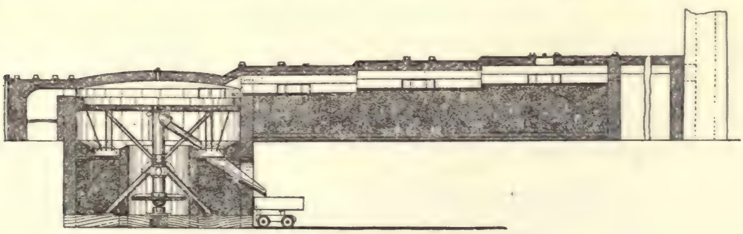


FIG. 2.—The rotary-pan furnace.

Thies and Phillips (*Trans. A. I. M. E.*, xix, 601) give the capacity of this furnace, roasting pyrites concentrates, as 3⅛ tons per 24 hours. A double-hearth reverberatory furnace with 400 sq. ft. hearth area, at the same place and with the same ore, desulphurizes 2⅔ tons per 24 hours. Each furnace consumes ½ cord of wood per ton of roasted ore, and requires the labor of 4 men, which is not very good practice compared with what is done with single-hearth reverberatory furnaces in the West.

The Spence Automatic Desulphurizing Furnace consists of a series of hearths placed one above another, with a mechanical device for raking and stirring the charge on each. Each hearth has an opening at alternate ends, through which the charge drops to the next hearth below. On each hearth there is a rake of nearly the same width as the hearth, which is moved backward and forward from end to end of the furnace by a rod working through a stuffing-box at one end. The ends of the rods outside the furnace are supported by a rack or carriage which travels on a railway. The necessary supply of air is admitted through adjust-

able ports below the lowest hearth. The number of hearths varies from three to seven, according to the character of the ore to be roasted. Connected with the furnace is a pair of 7 × 10 engines, which run at 40 revolutions per minute, and quietly and positively operate by means of geared wheels the rods to which the toothed rakes in the furnace are attached. The charge is raked at intervals of about five minutes, and in the mean while the rakes are pulled to the back end of the furnace and the driving-engines are stopped. Connected with the furnace there is also a small auxiliary engine, which runs constantly, and by suitable mechanism puts the large engines and rakes in operation at the proper times. The ore is fed into a hopper on the top of the furnace, and is gradually admitted to the latter through a port which is opened and closed by the movement of the rakes. Falling on to the uppermost hearth it is gradually worked along until it drops through the hole to the next hearth below, when it is worked backward, dropping on the third hearth, and so on. From the lowest hearth it is discharged into a bin or cars, through a port which is also opened and closed by the movement of the rakes. When the rakes have finished the forward stroke the engines reverse automatically, and the rack returns to position and stops until the auxiliary engine puts the driving-engines in operation for another cycle. This furnace was especially designed for roasting fine pyrites for the manufacture of sulphuric acid, and has given excellent results in that work, fine ore with from 40 to 47 per cent sulphur having been desulphurized to 1·5 to 2·5 per cent sulphur, at the rate of from 7½ to 10 tons per 24 hours. In roasting pyrites for sulphuric-acid manufacture no extraneous fire is used, the pyrites itself burning freely on the lower shelves. In roasting fine auriferous pyrites down to ¼ or ½ per cent sulphur preparatory to chlorination, a fire-box connected with the lowest shelf is used with the furnace. At the Treadwell mill, Douglas Island, Alaska, six Spence furnaces were used for desulphurizing pyrites concentrates for chlorination, with the result that slightly more than 3 tons per 24 hours were roasted "dead," with an expenditure of ⅛ cord of wood per ton of ore. Two men per shift attended to six furnaces.

The O'Hara Roasting-Furnace (Fig. 3) is a mechanical reverberatory furnace made with two separate hearths, one for desulphurizing and the other for chloridizing the ore, both

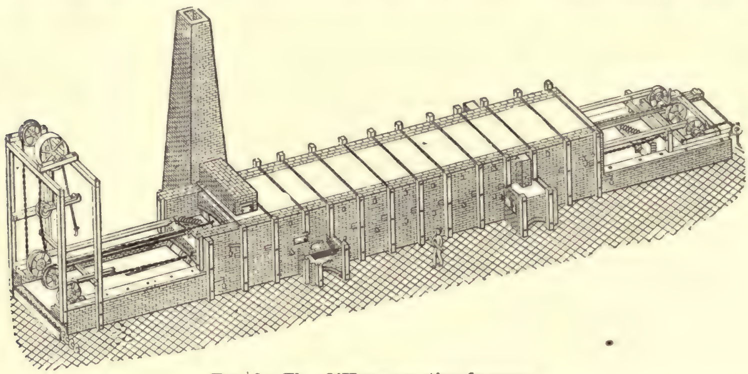


FIG. 3.—The O'Hara roasting-furnace.

processes being performed at one operation. Attached to an endless chain at proper distances apart are iron frames formed into a triangular shape; on these frames are a number of plows or hoes set at an angle. One set turn the ore toward the center, the next set turn it in an opposite direction toward the walls. These plows move through the ore every minute and expose a new surface of ore to the flames and gases. The space between the roof and hearth of each compartment is quite small, so as to confine the heat close to the ore. The operation of this furnace is as follows: The ore is fed continually into a hopper, through which it then falls on the upper hearth. The plows, actuated by the endless chain, stir the ore over and over on the hearth and move it gradually to the opening, where it falls to the lower hearth. As the ore is passed along in the upper compartment it is thoroughly desulphurized by the heat furnished by the fires, as described, and by the combustion of the sulphur in the ore. This action is assisted by the oxygen in the supply as admitted at intervals through the sides of the furnace by the openings. For a chloridizing roasting salt is mixed with the ore as it is fed into the hopper, and becomes thoroughly intermingled with it by the stirring action of the plows. When the ore falls through the opening and on to the lower hearth the fall breaks any spongy lumps or masses that may have been formed, and the ore is again stirred over and over, and moved along through the flame and gases over the lower hearth by the action of the plows toward the discharge-opening. The ore has become gradually more and more heated in its passage through the upper hearth, and by the time the extra heat is required as stated it comes immediately in front of the same fires which have during the whole process furnished the heat. Ordinarily the ore will be from five to ten hours in passing through the furnace, according to its character. Only one man is required to attend the fires, no other attention being necessary, as the ore may be fed to the furnace by mechanical means, and discharged from the furnace into a car, conveyer, or elevator. This furnace is also used with excellent results for oxidizing roasting.

CYLINDRICAL FURNACES.—*The Improved Brückner Roasting-Cylinder*, extensively used both for oxidizing and chloridizing roasting, consists of an iron cylinder, lined with fire-brick, and provided with two receiving and discharging doors midway in its length, which come directly under the charging hopper, and discharge directly into an iron hot-ore car placed underneath, or, if desired, into a pit. The cylinder revolves on four rollers, and is caused to rotate by spur gear-wheels driven by a worm-gear and pulleys. At one end of the furnace is an iron fire-box, mounted on brick foundations, and having a conical opening to match that on the cylinder, which is alike in form at both ends, the other end revolving close to the flue-opening. The furnace and its conical ends (throats) are lined throughout with fire-brick. Being of smaller diameter at the ends than at the center, the ore is thrown to and fro, changing its position frequently, and exposing new surfaces and particles to the action of the flames which draw through from the fire-box at one end to the flue at the other. These cylinders are commonly made in two sizes, viz.: 6 ft. diameter by 12 ft. long, weighing 15,000 lbs., which have an average capacity of 3 to 4 tons of ore; and 7 ft. diameter by 18 ft. long, weighing 28,000 lbs., with an average capacity of 6 to 8 tons. In the latest form of these cylinders the fire-box is really a car, running on a track at right angles to the longitudinal direction of the cylinders, and having a short flue in one side that comes exactly opposite the throat of the furnace. In this way the fire-box can be run opposite a cylinder which contains a fresh charge, and fired on until the sulphur is fairly kindled. Then the movable fire-box may be wheeled along to a neighboring cylinder, and the first one left to complete combustion of the sulphur with free access of air, and undisturbed by the reducing gases that pass up from an ordinary grate. After combustion of the sulphur it is necessary for a perfect roast to again connect the fire-box with the cylinder, and supply a little extraneous heat to complete the decomposition of the sulphates. It is estimated that two horse-power are required to drive a charged cylinder at an average speed. At the smelting-works of the Anaconda Mining Company, Anaconda, Mont., 156 Brückner cylinders are in constant use, desulphurizing ore containing about 35 per cent sulphur. The average charge is 9 tons, which in 24 hours is roasted down to 10 per cent sulphur, or in 36 hours to 3 per cent. For each cylinder 1 ton of Rock Springs coal (much inferior to that of Pennsylvania) is required per 24 hours. Two men attend to three furnaces. Dr. Peters states that the saving in cost in Butte, Mont., by using Brückner cylinders rather than reverberatory furnaces amounts to 40 per cent. Mr. R. H. Terhune states (*Trans. A. I. M. E.*, xvi, 18) that the best results obtained with the Brückner cylinder, 7 × 18 ft., with 4 in. brick lining, oxidizing roasting, at the Germania Smelting Works, near Salt Lake City, Utah, was the desulphurization of a charge of 8 tons down to 4 to 6 per cent sulphur, in 24 hours. The amount of fuel used (Pleasant Valley coal) was 20 per cent of the charge, and two men per shift of 12 hours attended to three furnaces. A cylinder 7 × 22 ft. in size was subsequently introduced at these works, and its results led Mr. James, the superintendent, to believe that the economic length of the Brückner furnace had been reached at 22 ft.

Arent's Improved Brückner Cylinder differs from the preceding in the shape of the roasting-chamber, which is not a true cylinder, but is made in the shape of a frustrum of a cone, its base being turned toward the fireplace. In this frustrum of a cone the ore seeks the same horizontal level when revolved around its axis as in the Brückner, and is thus forced to form a layer of graduating thickness in the chamber, with its thin end near the flue end and its thickest or deepest end toward the fireplace. The flame coming from the fireplace is, of course, hottest at that end; and there, in this furnace, it finds the most ore to heat. As the flame, in its passage through the roasting-chamber, loses in intensity, so the ore layer becomes thinner; and there is less and less ore to heat until the flue is reached. In this manner it is claimed that the charge is "done" simultaneously at all points throughout the roasting-chamber. This cylinder is usually made 18 ft. 6 in. long, 7 ft. 3 in. outside diameter at the large end, and 6 ft. 3 in. at the smaller end.

The White Roasting-Furnace (Fig. 4) consists of a long cast-iron revolving cylinder inclined toward the fire end, and fed at the upper end with crushed pulp from stamp batteries

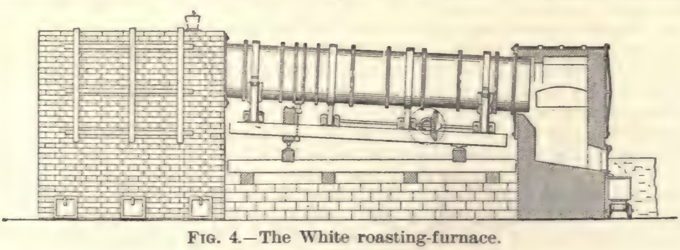


FIG. 4.—The White roasting-furnace.

or other pulverizer. The cylinder is made in sections to facilitate transportation. It is supported on four wheels or rings resting on truck-wheels and guided in a central position by rollers in upright frames, and revolved by friction of truck-wheels through gears and pulleys. The angle of inclination is changeable. The cylinder is lined with fire-brick throughout, and projecting bricks raise portions of the pulp and drop it through the flames, assisting the process. Salt for chloridizing is added before the pulp enters the cylinder. The advantages claimed for this furnace are that it is continuous in its operation,

discharging its product regularly into a pit at the lower end, and this roasted pulp need be withdrawn only as required; also that it submits the ore to a gradually increasing temperature, which is the true theory of perfect roasting. By changing the inclination, the ore can be retained to a longer or shorter period as necessary. The furnace is commonly made in three sizes, as follows: 40 in. by 24 ft., capacity 15 to 20 tons; 52 in. by 27 ft., capacity 20 to 30 tons; 60 in. by 27 ft., capacity 30 to 45 tons.

The Howell-White Roasting-Furnace is designed and works upon the same principle as the White, but has an auxiliary fireplace at the flue end, through the flames of which the dust from the roasting ore is drawn, and much that would otherwise pass off unoxidized or unchloridized is thereby roasted. The larger part of the cylinder at the fire end is lined with fire-brick, leaving the metal on the smaller portion exposed, as the greatest heat takes effect at the fire end. Cast-iron spirally arranged shelves assist in raising and showering the pulp through the flames. This furnace is fed in somewhat the same manner as the White, and is made in the same sizes, its capacity also being about the same.

Hofmann's Roasting-Furnace is an improved revolving cylinder furnace, with a fireplace and flue at each end. The flues are between the fireplace and cylinder, descending to the dust-chambers, which are connected with the main flue. The arrangement is alike on both sides. By means of dampers the current of the air and gases can be made to pass through the furnace in either direction. The object of this double fireplace arrangement is to enable the operator to expose the charge of ore to a uniform temperature. The fire is kept first on one place, with closed dampers on the same side, while the flue connection on the opposite side is open. After a few hours a fire is built in the other fire-box, and the position of the dampers is reversed. By changing the fire once or twice during roasting, both halves of the charge are exposed to the required temperature, without overheating one portion of the charge, thus, it is claimed, producing a higher and more uniform chlorination and diminishing the formation of balls. This furnace is especially suitable for ores which either require a very low roasting temperature or a very high one. By closing one of the large dampers near the main flue and opening the damper of the descending flue and corresponding plug-door, a current of live air can be made to enter the furnace together with the flame, thus assisting the combustion of the fire-gases and the oxidization of the ore. It is apparent that this arrangement permits the construction of cylinders of larger capacity than it is practical for furnaces with only one fireplace.

The Douglas Roasting-Furnace is a revolving cylindrical furnace with a fixed flue within the cylinder. The ore to be roasted is charged within the annular space between the outer shell and the central flue, through which the flames draw, as in the Brückner, White, and other furnaces of this class. This arrangement constitutes a revolving muffle, in fact, and it is claimed, makes a more efficient oxidizing furnace, as in the ordinary cylinder the flames, coming in direct contact with the ore, have a reducing action for a time after each firing. This evil effect is felt more in the cylinders, which are closed from end to end, than in the ordinary reverberatory furnace, which is furnished with a large number of side openings, by each of which more or less air enters to maintain oxidation. In the Douglas furnace the admission of air to the roasting ore is regulated by a register at the discharge end. The loss of heat by its transmission through the walls of the flue is trifling. The degree of heat required, even at the fireplace end of the cylinder, is small, and but very little of this escapes into the chimney after its passage through a flue of 30 ft. or so in length.

The central flue may be constructed of cast-iron pipe, supported by spiders, and the ore be agitated by shelves, as in the ordinary cylinder, but a square or triangular tile-flue, supported by heavy tiles built into the lining, is preferable. If the tiles be of good material and well locked together in the cylinder, the flue and its supporting shelves can not work loose or fall to pieces. Such a cylinder is converted into three or four muffles, and the ore is agitated by a gentle rolling motion, which, it is claimed, is preferable to the pounding action to which the particles are exposed when dropped from shelves, and which case-hardens them during the plastic state through which most ores pass in the early stage of roasting. Another advantage claimed for the flue consists in reducing the current of air in contact with the ore, and therefore the amount of dust carried into the dust-chamber. In order to burn the combustion gases, and supply the necessary surplus of oxygen to the ore, the amount of air and gas striking the ore in the ordinary cylinder is necessarily much greater and the current more rapid than that which is admitted to the roasting compartments only of the flue-cylinder.

An ore liable to sinter, such as galena, or matte rich in lead, as well as the higher grades of copper matte, can not safely be roasted in the confined inaccessible space of the cylinder; but all other ores and products can be calcined in this furnace.

Works for Reference: Roasting Gold and Silver Ores, by Guido Küstel, 1880; *Leaching Gold and Silver Ores*, by C. H. Aaron, 1881; *Metallurgy of Silver, Gold, and Mercury in the United States*, by T. Egleston, vol. i, 1887, vol. ii, 1890; *Metallurgy of Gold*, by Manuel Eissler, 1891; *Metallurgy of Silver*, by Manuel Eissler, 1889; *Modern American Methods of Copper-Smelting*, by E. D. Peters, Jr., 1891; *The Lixiviation of Silver Ores with Hyposulphite Solutions*, 1888; *Chloridizing, Roasting, and Lixiviation at Yedras*, by George J. Rockwell, *Engineering and Mining Journal*, February 4, 1888, *et seq.*

FURNACES, SMELTING. Smelting-furnaces may be divided into three general classes, viz., shaft-furnaces, reverberatory furnaces, and retort or closed-vessel furnaces. In furnaces of the first class the charge and fuel are in intimate contact, there being no independent hearth or fireplace. In furnaces of the second and third classes the fuel and ore are kept separate, the fuel being burned on an independent hearth. The Bessemer converter, used in

steel-making, and the Manhés converter, used in copper-smelting, are omitted from this classification. In lead-smelting in this country shaft-furnaces are invariably used; in copper-smelting, shaft or reverberatory furnaces, according to the character of the ore. The large shaft-furnaces used for the reduction of iron-ores are described elsewhere (see FURNACES, BLAST). For the reduction of zinc and quicksilver ores retort-furnaces are employed.

The shaft-furnaces used in lead and copper smelting are known as Pilz furnaces if their horizontal section is circular, or Raschette furnaces if it is rectangular. Pilz furnaces are now very little used. Although the circular form possesses certain advantages, experience has shown that the ordinary blast used in lead and copper smelting, seldom exceeding 1 lb. per sq. in., can not well penetrate to the center of a charge in a furnace of greater diameter than 50 in. The size, and consequently the capacity, of a Pilz furnace are therefore limited.

The general construction of the Raschette furnace, which is used in lead-smelting, is shown in Fig. 1. The crucible, resting upon a solid foundation, is built of fire-brick and lined with fire-clay, the whole being surrounded by a curb of thoroughly braced wrought-iron plates. Upon the brick-work within the curb is placed the water-jacket, which is make of wrought-iron boiler-plate in four parts, two side and two end pieces. It is so constructed that no seams appear next to the fire, and all four parts are bound by wrought-iron forgings, which can be quickly unfastened when necessary. Cast-iron spouts are riveted to the jackets for overflow and feed water. Hand-holes are also provided for cleaning out sediment, and in the side jackets are openings for the tuyères, the number of which vary with the size of the furnace. Four iron columns, resting upon the foundation of the furnace, support the brick-work above the water-jacket, the brick-work resting upon a deck-frame of wrought-iron I-beams, united by wrought-iron plates and bolts. Angle-iron corner-binders hold the brick-work against all cracking. The slag-spout is shown at the end of the furnace, the lead-well at the side, and the charging door just above the upper floor.

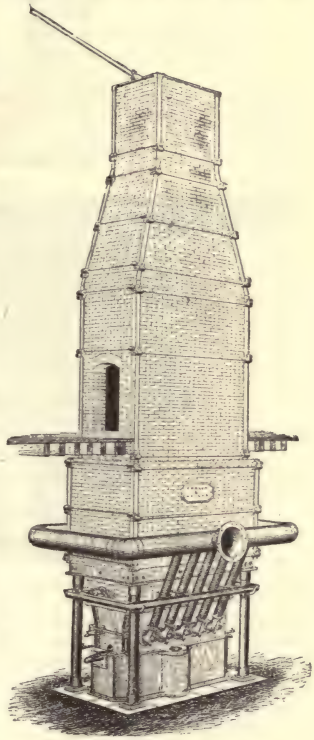


FIG. 1.—Raschette furnace.

The furnace is surrounded with a large pipe of galvanized iron, called the bustle-pipe, to receive the air-blast from the main blast-pipe and distribute it to the tuyères. The bustle pipe is connected with the tuyères by flexible pipes, usually made of canvas. The tuyères are short, conical iron pipes pointing into the furnace, passing through the water-jacket. The outer ends of the tuyères can be opened, so that a rod may be inserted to clear them of slag if they should become thus clogged. The furnace shown in Fig. 1 is equipped with the Devereux adjustable tuyères. These consist of a loose iron sleeve, cast with a central bore at a considerable angle, and capable of being quickly revolved by the hand to point the blast up or down at any angle between the extremes. The tuyère rests in the tuyère-hole formed by a bronze-metal tube in the water-jacket, and is thus cooled.

The average size of the Raschette furnaces used at Denver, Col., where the practice of lead-smelting has been carried to a higher degree of perfection than anywhere else in the world, is 33 in. wide and 100 in. long. The average amount of ore smelted in these furnaces is 40 tons per 24 hours. The largest furnace in use is 60 in. wide and 120 in. long, the water-cooled tuyères protruding 6 in. on either side. The capacity of this furnace is 80 tons per 24 hours. The average cost of smelting in Denver is $4.75 per ton, excluding the cost of roasting, which amounts to about $2 per ton. I am indebted to Prof. H. O. Hofman, of the Massachusetts Institute of Technology, for the foregoing figures.

The general construction of the Raschette furnace used for smelting copper-ores is similar to that used for lead, the main point of difference being the crucible. For the reduction of oxidized ores furnaces with an interior crucible are generally used. Fig. 2 shows a furnace of this type, 33 in. wide at the tuyères and 66 in. long, designed by Carl Henrich for the Detroit Copper Company's smelting-works at Morenci, Arizona. It consists of a lower and an upper water-jacket of wrought iron, the lower one supported from the cast-iron bottom plate and short columns, the upper one resting upon four long columns by means of cast-iron lugs or brackets. Between the lower jacket and bottom plate is a wrought-iron curb, confining the metal crucible, which is formed with fire-clay. Above the upper jacket is a short sheet-iron casing, extending to the charging floor and lined with one thickness of fire-brick, and containing the outlet for connection to dust-chamber. A floor-plate of cast iron is provided with inside hoppers. The stack is of telescope pattern, the stationary part being provided with roof-plate and umbrella, while the movable part is provided with balance-weights, that permit pushing it up out of the way when the furnace is in operation, and allows it to be quickly lowered when blowing out. Two water-jackets are introduced to provide a water-cooled surface from crucible to the top, in order to do away with brick almost entirely. Both

upper and lower jackets are made in four sections (two side and two end pieces). There are fourteen tuyères, five in each lower side jacket and two in each lower end jacket. Two distinct sets of water-pipes are provided for water supply and discharge. A galvanized bustle-pipe surrounds the furnace, and connection to tuyère elbows and nozzles is made by canvas hose. The tuyère elbows or nozzles are provided with a ball-end, which makes a universally adjustable joint in the tuyère, which is made to suit it.

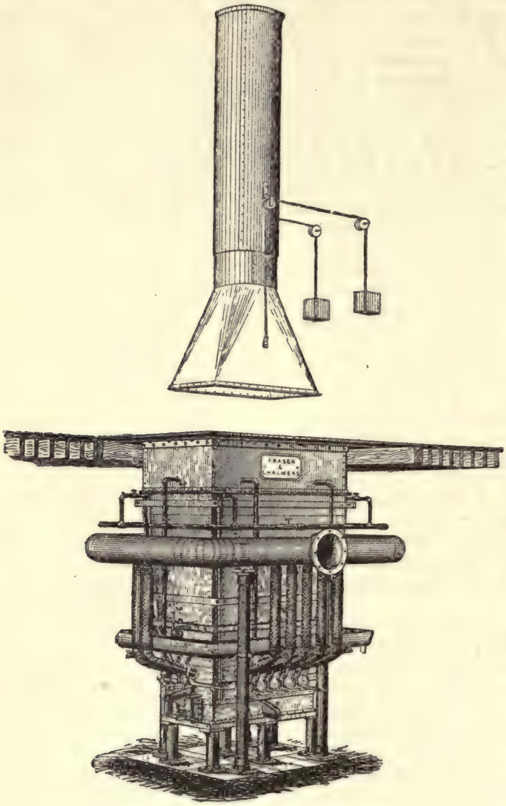


FIG. 2.—Raschette furnace.

The cross-section of this furnace at the tuyères is 33 × 66 in., while 10 in. higher up a bosh is begun, so that 30 in. above the tuyères the cross-section is enlarged to 45 × 78 in. The four lower cast-iron jackets terminate at this point, where they are surmounted by the other four, which still diverge slightly, so that at their upper surface, 7 ft. 6 in. above the tuyères, the furnace has an inside section of 54 × 87 in., which is retained to the charging door, 10 ft. 6 in. above the tuyères. The slag top is 6 in. below the latter, and the crucible is 14 in. deep, lined with brick, and provided with a drop bottom. The object of the bosh is to increase the reducing action, with the view of obtaining cleaner slags.

In smelting sulphide ores the American practice of the present day is to do away entirely with the ordinary deep crucible, substituting for it merely a sloping bottom a foot or less below the tuyères, from which the entire molten material escapes through a narrow groove under the breast, then first entering an outside crucible or well, in which the matte separates from the slag and is tapped into molds, while the slag flows from a spout into iron pots arranged on wheels for convenient dumping. In this manner, chilling over the metal in the crucible and the troublesome freezing of the tap-hole are avoided. The formation of sows is also prevented by the immediate escape of the fused ore from the powerful reducing action of the fuel. Provision is made to prevent any escape of blast under the breast, either by so thoroughly covering the orifice and channel that only a minute groove exists, which is constantly filled to its utmost capacity with molten ore, which soon forms an impervious cover to its channel; or by so raising the terminal slag-spout, and lowering the anterior wall of the furnace, that the blast is securely trapped, just as sewer-gas is prevented from escaping in an ordinary drain. This system of exterior crucibles was introduced in this country by Mr. James Douglas, Jr., at his Phœnixville Works in 1879.

The height of the furnace depends upon the character of the ore and the quality of the fuel; refractory, siliceous ore, and dense, strong coke requiring and permitting the employment of a higher furnace than the opposite conditions. With basic and easily fusible ores any height above 10 ft. (from tuyères to charging door) is rarely met with; even with refractory ores the danger of reducing metallic iron and the general unmanageability of a high furnace practically limits the height to 14 ft. Dr. E. D. Peters gives the cost of smelting an easily fusible copper-ore in a circular water-jacket furnace, 42 in. in diameter, having a capacity of 56 tons per 24 hours, as $1.98 per ton in the East, and $6.40 per ton in Arizona.

The Herreshoff Furnace is a modification of the above. It has a fire-hearth, or well, which is sometimes, for convenience of removal, placed on wheels, though more frequently it rests upon solid ground. The bottom of the furnace consists merely of a circular, concave, cast-iron plate, firmly bolted to the lower border of the water-jacket, which extends about 12 in. below the tuyères. The bottom is covered with a single course of fire-brick resting on a shallow layer of sand. The outlet of the furnace is a small circular opening in the water-jacket. There is a similar opening in the back wall of the movable hearth, which is protected by a small, separate water-jacket. Thus is formed a short, water-cooled channel from the furnace to the fire-hearth. The slag-discharge from the fore-hearth is several inches higher than this channel, so that the latter is covered several inches deep with molten material, and the blast is completely trapped. The slag runs out from the fore-hearth continuously; the matte is tapped at intervals. In the latter operation the slag-spout is plugged with a ball of plastic clay, so

that the blast is tightly confined even after the molten material has descended below the top of the channel from the furnace. As it is sometimes impossible or inadvisable to close the tap-hole in the fore-hearth at the exact moment when the last of the matte has escaped and the first of the slag begins to flow, a tilting launder is arranged between the matte-spout and the molds, which, when held up by a chain, conducts the liquid to the regular molds, but when released by a catch, turns upon a horizontal pivot and conveys the slag in the opposite direction, where it is cast in proper shape for resmelting.

According to Dr. E. D. Peters, from whose *Modern American Methods of Copper-Smelting* this description is taken, the cost of smelting in a large Herreshoff furnace is very low. The number of men required per furnace is 10. With gas-house coke and repairs exceptionally low, the cost per ton of ore at the Laurel Hill Chemical Works, Long Island City, N. Y., does not aggregate 80 cents per ton of ore. The average charge of ore in the 48-in. circular furnace at those works was 56 tons per 24 hours, and of the 60-in. furnace 84 tons. At Butte, Mont., a 48-in. furnace, with 6 2-in. tuyères and ¾-lb. blast, smelted from 60 to 65 tons of calcined pyritic concentrates daily.

Elliptical cupola furnaces, provided with sectional cast-iron jackets, forming a bosh 29 in. high immediately above the tuyère level, are used for treating the slags resulting from the fusion of the "mineral" of Lake Superior in reverberatory furnaces. In these cupolas, in place of distinct tuyère-openings, a ⅝-in. slot encircles the entire furnace, just below the water-bosh. Below the tuyères is a crucible 34 in. deep, nearly the full size of the furnace, closed by a drop-bottom. The water-bosh, which is 22 in. high, consists of curved sections of cast iron, fitted closely together. The cupola is 7 ft. 6 in. high, from tuyères to charging door, and has a major axis of 7 ft. and a minor axis of 4 ft. 9 in.

Reverberatory Furnaces are constructed of very varied forms and dimensions, but the principles of all are the same. They consist of two main portions—the fireplace (either an ordinary grate or a gas-producer) and the laboratory part, the fuel being separated from the ore, or the materials to be heated, by means of a fire-bridge, which is simply a wall of refractory brick, usually furnished with an air-channel to keep it cool. The flames draw over this bridge and reverberate into the laboratory part, which is connected by means of a flue with the chimney, which serves for the withdrawal of the consumed gases and the production of draft. The reverberatory slagging-furnace used in lead-smelting is a modification of the reverberatory roasting-furnace (see FURNACES, ROASTING). It has two hearths, one a step higher than the other, the lower hearth being next the fire-bridge. The raw ore, having been fed in at the flue end of the furnace, is gradually worked forward, being desulphurized on the way, and is finally pushed down to the lower hearth, where the heat is more intense, and the ore is fused or agglomerated, thus preparing it for the blast-furnaces. This practice is not pursued everywhere, in many places it being the custom to feed the roasted ore to the blast-furnaces without slagging. At Denver and Pueblo, Col., however, the tendency seems to be distinctly in favor of the preliminary slagging.

Reverberatory furnaces for copper-smelting are in general use in Swansea, and the method is, in fact, distinctly Welsh. In certain copper regions of the United States, also, furnaces of this class are exclusively used. The American reverberatories are modeled closely after those of Wales, which have been in use for many years, the only improvements having been in their size, which there is a constant tendency to increase, with the consequent gain in capacity. The hearth of the copper-reverberatory is usually an elongated oval, the exterior shape of the furnace being rectangular, however. In an ordinary furnace the hearth is about 15 ft. long and 10 ft. wide, the capacity of a furnace of this size being about 16 tons per 24 hours. At the works of the Boston & Colorado Smelting Co., at Argo, Col., Mr. Richard Pearce has introduced furnaces with hearths 24 × 14 ft., thereby increasing the capacity to over 28 tons per 24 hours.

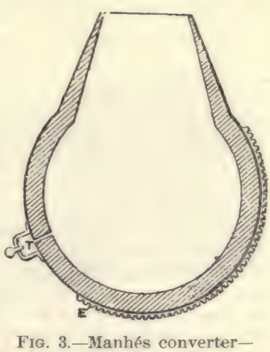


FIG. 3.—Manhés converter—section.

Within the past ten years an important improvement has been made in copper-smelting by the introduction by M. Manhés of a system of Bessemerizing copper matte, and the process is now being quite extensively used. The improved Manhés converter, such as is used at the Jerez-Lanteira smelting-works in Spain, is shown in Figs. 3 and 4, of which the former represents a transverse section of the converter, and the latter a side elevation of the converter and its carriage. The apparatus consists of an iron cylinder 4 ft. 3 in. in length, having an outer diameter of 4 ft. 2 in. It is made of iron plates ¾ in. thick. In the upper part of the cylinder there is an opening on which a conical chimney is riveted, the highest part of which has a diameter of 22 in. On one side of the cylinder, and all along its length, an air-chamber, *C*, is fixed, of rectangular shape, and in this 11 tuyères, *T T*, of ⅘ in. diameter are inserted. In front of each tuyère there is a hole made in the outside of the air reservoir, which is closed by a wooden stopper. Through these holes the tuyères are kept free for the entrance of the air. At one of the ends of the air reservoir tubes, *A*, are fixed for the entrance of the blast, and these tubes are so arranged that, the highest being connected with the air main, whatever position the converter takes on turning on its axis, the supply of air is kept up uninterruptedly. On the outside of the converter, and at half of its length, a toothed segment, *E*, is placed, for the purpose of moving the converter on its axis in the manner to be described

hereafter. On both sides of this toothed segment, and about 12 in. from the end of the converter, two flat ribs of iron are placed. Lastly, in the upper part of the converter two strong hooks are provided to lift it by means of a crane or differential pulley-block whenever required.

The carriage which supports the converter runs on rails, and each wheel has fastened to it a toothed wheel which gears into a small pinion. By means of the handles, *M*, the wheels are turned, giving to the carriage a smooth forward or backward movement. On the carriage there are four loose wheels, *R*, on which the converter rests, and which facilitate the movement of the converter round its axis. For the purpose of complete movement the carriage carries a shaft, in the center of which is a worm-wheel geared to the tooth segment, *E*. The shaft, when operated by the handle, *M*, places the converter in the inclined position suitable for loading, unloading, blowing, or discharging the slag as it may be required.

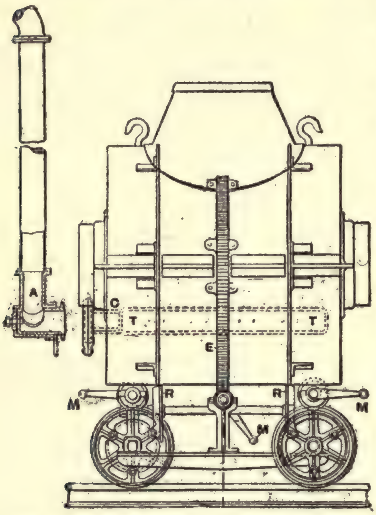


FIG. 4.—Manhés converter and carriage.

The operation of the Manhés process at Jerez-Lanteira is thus described by Señor Sanchez Massia, who is in charge of the works there: The carriage runs on rails placed at a level 5 ft. lower than the floor of the blast-furnace in which the matte is made, and on being brought in front of the same the handle, *M*, is turned, and the converter is inclined so as to allow the matte to run into it. When the charge is in the converter this is raised to a vertical position, and is carried under the chimney for the outlet of the gases and fumes, and after being thus placed the air-chamber is connected with the air-main. The air is then admitted, and the converter inclined so that the air may enter and go through the charge at a convenient depth. This depth varies with the quality and composition of the matte treated, and may also vary at different stages of the operation. The blast oxidizes the sulphur, arsenic, and antimony, and these pass to the chimney, while the non-volatile impurities are also oxidized and combine with the silica of the lining. Sometimes silica is added to the charge, by which means the lining is made to last longer. Usually a lining lasts for 24 hours, and for continual work three converters should be kept, which is easy enough, as the cost of each is only about $500. Should the slag be in excess, the blowing is stopped and the converter inclined to let out a part of it; then the converter is brought to its proper position and the blowing continued. During the operation a man is kept continually at work to clear the tuyères, and, as particles of slag and matte are expelled from the converter, the men in attendance are protected by a kind of horizontal umbrella of iron fixed on their shoulders. The end of the operation is recognized by the intense green color of the flame, which indicates that some copper is being burned. At this stage the blowing is stopped, the converter inclined, the slag raked out, and the copper run into ingot-molds.

Whatever may be the quality of the matte acted upon, success can always be attained, since this depends upon the depth at which the charge is blown. This depth can always be regulated by the inclination of the converter. The weight of the charge may vary within wide limits, but at Jerez-Lanteira it is usually one ton. The time employed in treating each charge varies from 20 to 40 minutes, according to the yield of the matte, the shortest time being for the richest matte. The heat left by one charge in the converter is enough for the next, and therefore, when the working of the converter does not keep pace with the smelting of the ores, it is better to store the excess of matte and remelt it again. The amount of coke used for smelting is 8 per cent of the weight of the matte. The slag always contains some copper, and for this reason it is usually sent back to be passed through the cupola. The fumes from the converter are made to pass through a gallery 55 m. in length, with the object of collecting some of the antimony contained in the ores.

When the Manhés system of dealing with copper mattes is compared with the usual method, a very great economy of fuel is claimed. At Jerez-Lanteira, where water-power is used for the blowing-engines, the fuel consumed is only one seventh of what would be required in the usual method. The mattes from which the best results are obtained are those containing 20 per cent iron and 25 per cent sulphur. The air is injected at a pressure of half an atmosphere, or, say, 7½ lbs. per sq. in. This process has been introduced at the works of the Parrot Silver and Copper Co., at Butte, Mont., with very good results.

Works for reference: *Modern American Methods of Copper-Smelting*, by E. D. Peters, Jr., 1891; *Copper-Smelting*, by H. M. Howe; *Copper-Smelting, its History and Processes*, by H. H. Vivian, 1881; *Elements of Metallurgy*, by J. A. Phillips, 1887; *Introduction to the Study of Metallurgy*, by W. C. Roberts-Austen, 1891; The Mines and Reduction Works of Butte, Mont., by E. D. Peters, Jr., *Mineral Resources of the United States*, 1885; Copper Refining in the United States, by T. Egleston, *Transactions American Institute Mining Engineers*, vol. ix; The Basic Process applied to Copper-Smelting, by Percy C. Gilchrist, *Journal of the Society of Chemical Industry*, January, 1891; The Bessemeriz'ng of Copper Mattes, by T. Egleston, *School of Mines Quarterly*, May, 1885; Lead Slags, by M. W. Iles, *Mineral*

Resources of the United States, 1883 and 1884; Lead-Smelting, by O. H. Hahn, *Mineral Resources of the United States*, 1886; The Desilverization of Lead, by H. O. Hofmann, *Mineral Resources of the United States*, 1887.

Fuse: see Torpedo.

Gadding: see Quarrying-Machines.

GAINING-MACHINES. Gaining is grooving at right angles to the fiber of the wood, or, more properly, to the length of the stick or plank; and it may be done by routing-tools, cutting both with their ends and with their sides, making a channel by reason of the tool and the timber having relative motion to each other at right angles to the length of the stick; or by saws or cutters mounted on an axis parallel with the face of the timber, and working the groove with their peripheral cutters; or by a saw having a wobbling motion by reason of being set at an angle to an axis parallel with the face and length of the piece.

In some of the most improved gaining-machinery the reciprocating motion of the cutters is at the same speed back and forth across the timber, so that cutting can be from either side or both, as desired. In others the table has stops—sometimes as many as 12 in number—which are set to locate the position of the gains lengthwise of the timber; and the depth to which the cutters act is determined by movable stops in the front saddle on which the spindle is carried, so that, when the machine is once set for a particular kind of work, no laying out is required for duplication. In others, again, there is a boring attachment, having both horizontal and vertical movement, and a radial adjustment by which angular holes may be bored.

The Bentel & Margedant Gaining-Machines.—In the automatic traverse gaining-machine, made by the Bentel & Margedant Co., for cross-gaining, square, angular, and double-angular gaining, a special point is the arrangement for feeding the cutter-head and carriage across the table, either by hand or by power feed. The machine bears a horizontal mandrel across its front face, a cutter-head to the right, and a table in front. By pressing a lever at the top, either to the right or to the left, the cutter-head is made to move across the table with long or short stroke, as desired, by power; or the same motion may be more slowly imparted by operating a hand-wheel in front of the cutter-head mandrel. A horizontal gang-gaining or grooving machine made by the same firm, and brought out during the spring of 1892, is intended for cutting a number of grooves or gains at once. There is a long horizontal mandrel, bearing a number of heads which are adjustable in their distance apart. The material is clamped and held securely on the table which moves across the machine under the cutter-heads. It has both power and hand feed. Its use is specially appropriate for making filing-cases, desks, and similar work. It takes in work up to 8 ft. 2 in. long and 24 in. wide.

The Berry & Orton Gaining-Machine.—A machine which is a combination of a cross-gainer and grooving machine, and a three-spindle vertical boring-machine, is made by Berry & Orton. It has a carriage or table as long as the longest timbers to be worked, mounted on roll-stands so as to be readily and rapidly moved by power or hand; and this has right and left traverse in front of two columns, one of which, to the left, bears the vertical boring-spindles, and the other, to the right, the cross-gaining head. The carriage has the same stops and bolsters as are mentioned in connection with the gaining-machine; and the three spindles of the boring-machine have both vertical and horizontal adjustment, and are brought to their work by counter-balanced levers. The object of this machine is to save handling by doing all the operations of gaining, grooving, and boring of a piece of timber when once in position on the table.

The Fay Groover-Head.—A very desirable addition to grooving-machines is the solid expansion groover-head, shown in Fig. 1, and which is arranged so that without removing or changing the cutters they will extend to double their width. There are two disks, having a distance-washer between them, and each bearing a toothed scoring-bit on each side. There are also in each disk slots which receive the edges of gaining-bits having the minimum width which it is desired to gain with the head. For gaining this minimum width each of the gaining-bits is held by both the disks; but for increasing the width the disks are placed farther apart, so that each bit is held by only one edge, in only one disk.

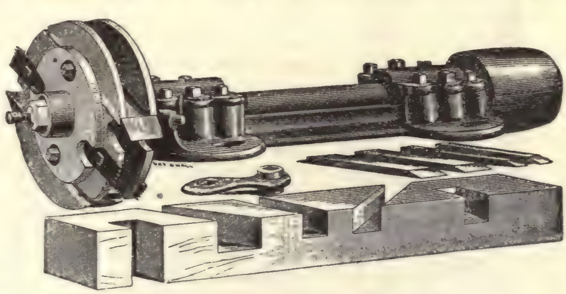


FIG. 1.—Fay groover-head.

The Hoyt Groover-Head.—An expansion-gaining or grooving-head, made by Hoyt & Bro., consists of a hub having two radial projections, on each of which there is bolted a tool-holder, each tool-holder bearing two tools, one of which is parallel to the radial projections from the hub, and the other at a desirable angle thereto. By set-screws these tools may be set in and out so as to cut to a greater or less width.

In the use of the gaining-machine it must be remembered that one head will do for all work when the width of the gains exceeds that of the cutters; although, of course, where there are many gains to be cut of a width greater than any cutter on hand, it may be best to

use wider cutters in order to save the time of the machine. This is a commercial question, the solution of which must be effected on the ground and with full knowledge of the conditions; but it is well to remember that the machine lends itself to either way of working. One piece of work to which the gaining-machine is specially well adapted is in the preparation of hatch-gratings, or other light work of that character, where a number of pieces can be done at once and with accuracy, so that they will fit together in erecting.

Gap-Lathe: see Lathes, Metal-Working.

Gas-Engines: see Engines, Gas. **Gas, Fuel**: see Gas-Producers. **Gas-Furnace**: see Furnaces, Gas. **Gas-Generator**: see Aërial-Navigation. **Gas-Pressure Regulator**: see Regulators.

Gaskets, Packing: see Packing.

GAS-PRODUCERS. GAS-FUEL.—The increasing use of various kinds of gas as fuel, both in the industrial arts and for domestic purposes, makes important a knowledge of the different processes for producing fuel-gas, and of the heat-giving power of the several kinds. An elaborate study of this subject is given in a paper by W. J. Taylor, read before the American Institute of Mining Engineers, February, 1890 (*Transactions*, vol. xviii).

"The extravagant claim," says Mr. Taylor, "of some oil-gas advocates is still heard, that by vaporizing oil with steam and then passing the mixture through a coil of hot iron pipe, an oil-water-gas containing 26,600 heat-units is formed from 1 lb. of oil carrying originally 21,000 heat-units, while the only energy expended on the gas has been by the introduction of a little steam and a little extraneous heat. Theoretically, 1 lb. of oil converted into water-gas carries 26,600 heat-units, but this is only obtainable by a large expenditure of energy, the amount of which is difficult to calculate; even with apparatus of theoretically perfect efficiency, it could not be less than the quantity of heat added to the calorific energy of the oil. The cheapest artificial fuel-gas per unit of heat is common producer-gas, or "air-gas," as it might be termed, since the oxygen for burning carbon to carbon monoxide is derived mainly from air. The associated atmospheric nitrogen dilutes the carbon monoxide. making air-gas the weakest of all useful gases—that is, the lowest in combustible, both by weight and by volume. Next in the order of heat-energy comes water-gas, in which the oxygen for combining with carbon to form carbon monoxide is derived from water-vapor, and hydrogen is liberated. For equal volumes, this gas has more than double the calorific power of air-gas. Third in the ascending scale stands coal-gas, the ordinary illuminating gas distilled from bituminous coal, which carries more than double the heat-energy of water-gas. Last, and highest in the list, is natural gas, which we can not duplicate in practice by any known process. The calorific power of natural gas is about 50 per cent greater than that of coal-gas. The introduction of natural gas for metallurgical purposes has largely stimulated the production and use of artificial gas made from coal and from oil, if the vapors of the latter can be fairly considered a gas."

The Loomis Gas Process.—This process was introduced in 1887, and has come into extended use in the United States and Europe, producing gas for fuel and illuminating purposes from bituminous slack coal, anthracite screenings, and other low-cost fuels. Essentially a water-gas process, the producer or blast-gases of excellent quality are successfully applied to industrial work, making in combination with the water-gas a very economical fuel-gas plant. Fuel-gas made by this process is being distributed in cities and towns for domestic uses, and is applied to a great variety of industrial work, such as steel-melting, melting iron, brass, copper, silver, and other metals, tube and plate welding, smiths' forges, reheating, hardening, tempering, and annealing furnaces, pottery-kilns, etc. For illuminating purposes the water-gas is either carbureted or the non-luminous gas used with incandescent burners, such as the Welsbach. Figs. 1 and 2 show sections of the generator, which is a cylindrical iron or steel shell 7 to 10 ft. in diameter, and from 12 to 14 ft. in height, lined with fire-brick. a is the top door for feeding fuel and supplying air for combustion, d is the water-gas outlet, M and N cleaning doors, b fire-brick arches for grate, C passage for producer-gas to cooler. Figs. 3 and 4 represent complete plant of two generators. With fire in the generator, the exhauster D draws air into the top door a down through the bed of fuel, the resultant producer-gas being drawn up through the vertical cooling-boiler C to the exhauster, and by it delivered into the producer-gas holder. When the fuel is in a state of incandescence the top door a is closed, and the blast stopped by closing the valve B; steam being admitted at E passes up through the hot carbon, the resultant water-gas passing out at the top of the generator through the seal F and scrubber G to the water-gas holder. Producer-gas can be made continuously, and enriched by admitting steam into the top of the generator. The quantity of water and producer gas varies with the kind and quality of the fuel used and the method of operating. The average make is from 35,000 to 45,000 cub. ft. of water-gas, and from 100,000 to 150,000 cub. ft. of producer-gas, from a ton of coal.

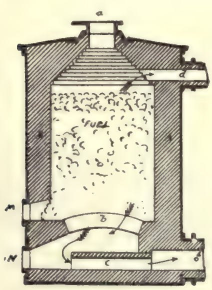


FIG. 1.

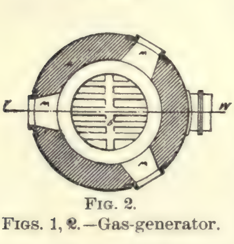


FIG. 2.

FIGS. 1, 2.—Gas-generator.

The following analyses are of gases of an average quality, and not made under exceptional conditions:

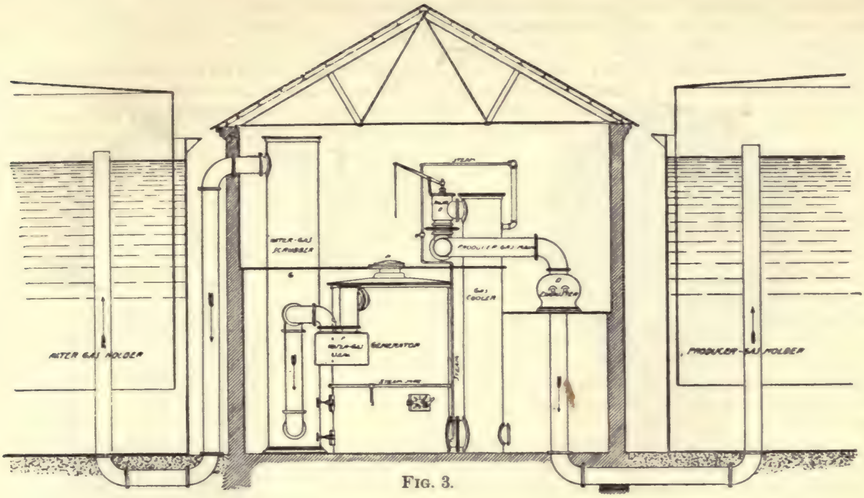


FIG. 3.

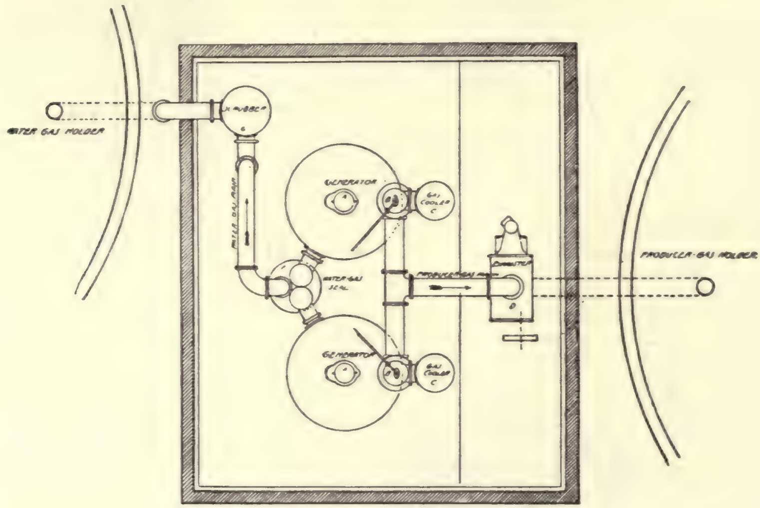


FIG. 4.

FIGS. 3, 4.—The Loomis fuel-gas process.

Water-gas.		
CO_2	4·00	
CO	28·60	90·72 combustible.
H	55·76	
Heavy hydrocarbon	0·40	
Marsh-gas	5·96	
N	5·28	
	100·00	

Producer-gas.		
CO_2	3·00	
CO	25·00	32·30 combustible.
H	7·30	
N	64·70	
	100·00	

The Rose Fuel-Gas Process is a combined water and oil gas method, the principal object aimed at being the thorough decomposition of the hydrocarbons by injecting them in small quantities at a number of different points, thus avoiding the cooling down of the apparatus which would grow out of the introduction of large quantities of hydrocarbons at any one point. The process will be found fully described in United States letters patent to J. M. Rose, dated October 13, 1891.

The Archer Fuel-Gas Process has recently been introduced into iron and steel works in the United States with very satisfactory results. Crude Lima oil is generally the fuel used, but other low-class oils or residuum left from crude oil after the illuminating oil has been removed are also suitable. The oil is forced by a small pump through a ½-in. pipe into the producer in which the gas is made. During its passage from the pump to the producer the oil is heated by passing through a coil of pipes forming part of the apparatus. On reaching the vaporizers the oil is brought into contact with steam, superheated in a similar manner, by which it is instantaneously decomposed, and a gas of great heating power is the result.

For heating purposes the gas is conveyed immediately as it is made through pipes to the furnace or burner, where, by the admixture of atmospheric air, perfect combustion is obtained in the process of consumption.

Taylor's Revolving Bottom Gas-Producer is shown in Fig. 5. The object of the revolving bottom is to avoid the difficulty of getting rid of the ash and clinker common to all the older forms of producers with stationary grates. The revolving bottom is of greater diameter than the bottom of the combustion-chamber, and placed at such a distance therefrom that, when it is revolved, the ash, which forms its own dome or slope at an angle of about 55°, is discharged uniformly by its own gravitation over the periphery and into the sealed ash-pit below (which is under pressure), all without stopping the producer, or much interference with making gas. The grinding is done as fast as the ash rises too far above the central air and steam discharge, say every 6 to 24 hours, according to the rate of working. The door of the ash-pit is opened once a day for taking out the ash and clinker. The injected air and steam are introduced through a central pipe and discharged radially therefrom, in order to prevent too much travel of the gas next the walls, which is the line of least resistance, the opening being placed at a point sufficiently high to clear the required bed of ash.

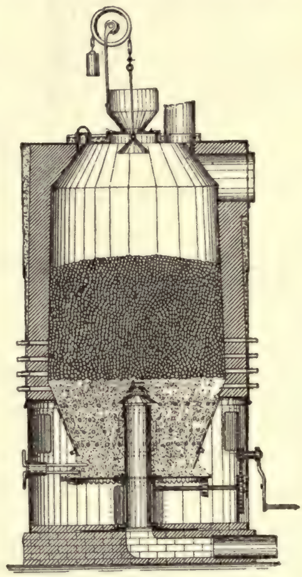


Fig. 5.—Taylor's gas-producer.

The American Oil-Gas Machine, recently invented by E. P. Reichelm and George Machlet, Jr., of the American Gas-Furnace Co., is described by the inventors as follows: "The oil is disintegrated by contact with a powerful stream of air, which enters through the bottom of the generator. The resulting spray is driven successively through a number of compartments closed by perforated disks, the holes in which are graded in fineness upward, each hole or perforation acting as a spraying tube, and this spray becomes finer and finer until the topmost disk discharges only a homogeneous mixture of air and atomized oil. The violent atomizing of the oil produces intense cold, and the moisture contained in the injected air is condensed and frozen into small bodies of ice, which return with the oil that does not pass from the generator as gas to a tank below it, where it melts and deposits as water. The desired pressure in the generator and the proportionate supply of oil are maintained by self-acting devices. The oil returning from the generator unconverted is resubjected to the spraying process until converted. The returning oil only comes in contact with the fresh air injected, while fresh oil, which is fed into a separate compartment, replaces the oil converted into gas. The gas is of good quality for mechanical purposes, producing a minimum of oxidation."

GAUGE-SAW. On all sawing-machines it is desirable to have a gauge which is at once accurate and easily operated. There are numbers of them upon the market, some for square work only, others only for bevel work. One which is shown (Fig. 1) is a combination gauge, made by H. L. Beach, for both square and beveled sawing. Its essential or main feature is the use of an eccentric and lever for locking its two adjustable portions. There is a sliding piece running in a groove regulating the distance of the gauge from the saw-disk; and this, by a single motion of its lever, is loosened or tightened. The fence proper is pivoted on a horizontal axis, and may be set at any degree of bevel with the vertical, as indicated by a pointer and a graduated circumference; the same simple eccentric and lever loosening or locking it by a pinching device. There are two adjusting set-screws for keeping it in alignment with the saw. It may be readily attached to any common saw-table.

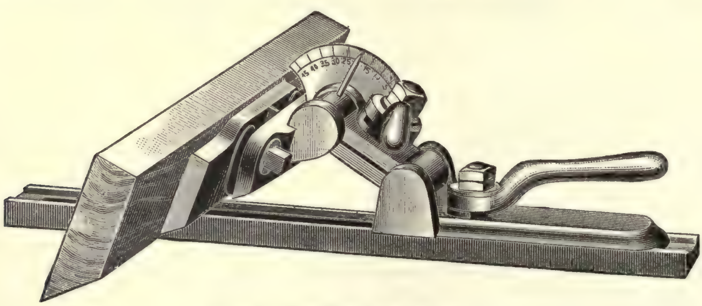


Fig. 1.—Combination gauge-saw.

Gauge: see Measuring Instruments, Mechanical. **Gauge-Lathe**: see Lathes, Wood-Working.

GAUGES, STEAM. *Bristol's Recording Pressure-Gauge.*—This instrument (shown in Figs. 1 and 2) is a recent invention of Prof. W. H. Bristol, of the Stevens Institute of Technology. Fig. 1 represents the instrument complete and ready for application. Fig. 2 shows the pressure-tube with the inking-pointer attached; the front of case, dial, and cover of clock

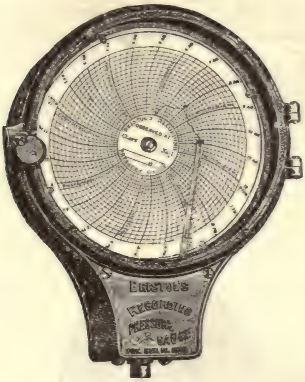


FIG. 1.

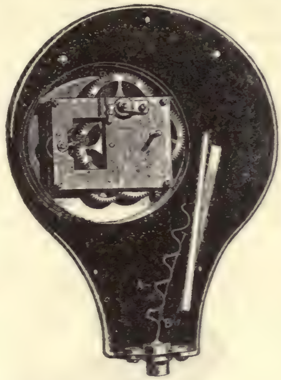


FIG. 2.

FIGS. 1, 2.—Bristol's recording pressure-gauge.

being removed. The pressure-tube *A* is of flattened cross-section, and bent into approximately a sinusoidal form. A flexible strip *B*, of the same metal as the tube, is secured at the ends and along the bands, as shown in Fig. 2. The bent tube may be considered as a series of Bourdon springs placed end to end. Pressure applied to the tube produces a tendency to straighten each bend, or collectively to elongate the whole. This tendency to lengthen the tube is resisted by the flexible strip *B*, and thereby converted into a multiplied lateral motion. The inking-pointer is attached directly to the end of the pressure-tube, as shown in Fig. 2. The usual mechanism and multiplying devices are dispensed with, since the motion of the tube itself is positive and of sufficient range. The special advantage of this is evident, considering that in all other pressure-gauges the movement of the tube or diaphragm is small, and requires a system of mechanism to multiply the motion many times before it is available for indicating purposes. These multiplying devices, even under the most favorable conditions, are liable at any moment to be a source of error. In the instrument illustrated the tube is designed for a range of 180 lbs. per sq. in.; for other ranges its sensitiveness may be varied at will, by changing its proportions, as length, shape of cross-section, or thickness. The printed charts for receiving the record make one revolution in 24 hours, and are provided with radial arcs and concentric circles, the divisions on the radial arcs corresponding to differences in pressure, while those on the concentric circles correspond to the hours of the day and night. The instrument is adapted for a vacuum as well as for a pressure-gauge, and, if sufficiently sensitive, it will serve as a barometer, and measure changes of atmospheric pressure. Another application of the pressure-tube is in the recording thermometer. The tube may be filled with a very expansible liquid, such as alcohol, and sealed. Variations in temperature produce expansion of the inclosed liquid, which in turn give deflections of the tube to correspond.

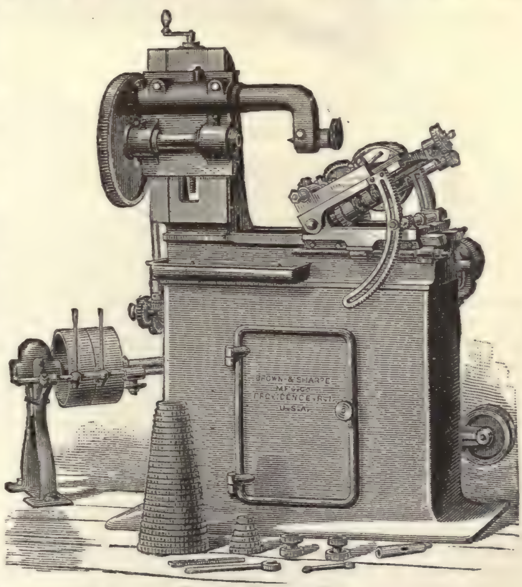


FIG. 1.—Gear-cutter.

GEAR-CUTTING MACHINES. *Brown & Sharpe's Automatic Gear-Cutter*, shown in Fig. 1, is automatic in all its motions, cutting through for each tooth, and revolving the wheel until all the teeth are cut, thus enabling the operator to attend to other work. The indexing is done by a worm and worm-wheel moved by change-gears. The blank being put in place, and the cutter-head adjusted for length of stroke, the wheel is lowered by a screw having a dial reading to thousandths of an inch, until

the proper depth of cut is obtained, when the cutter passes through the blank and back by a quick return movement; the wheel is then moved the proper distance for the next tooth, and so on until finished. The cutter-head is adjustable at any angle for cutting bevel-wheels, the degrees being marked on a graduated arc, no other change being required. There is also provision for moving the cutter out of center each way, for cutting bevel-wheels.

Bilgram's Bevel-Gear Cutter is shown in Figs. 2 and 3. The principle of the machine is explained as follows: It is possible to make with any system of interchangeable gears a rack

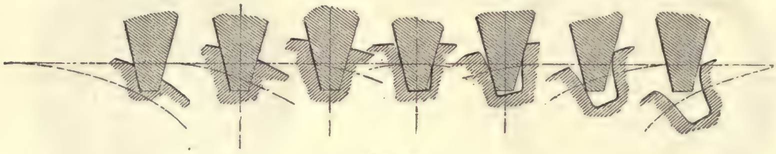


FIG. 2.

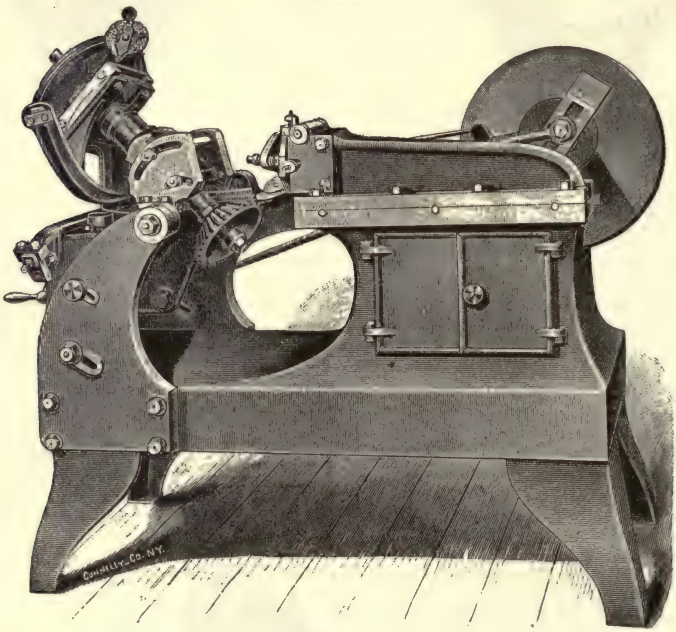


FIG. 3.

FIGS. 2, 3.—Bilgram's bevel-gear cutter.

which will correctly gear with any wheel of the set. Any wheel that gears correctly with this rack must therefore also gear correctly with any other wheel of the set; and from this it follows that if any number of wheels are made to gear correctly with this rack, they must also gear correctly with one another. If the wheels were made of some soft material, say wax, the teeth could be formed by simply rolling the blank into the rack, care being taken that the pitch-line of the blank will roll on that of the rack without slip. The desirable clearance can be obtained by giving this rack just the converse of clearance. Gears are, however, made of material that can not be removed by pressure, and the process must therefore be modified. The teeth of the rack might be made of hardened steel, with sharp edges at the ends; and by giving them a lateral motion the material could be cut away instead of being pressed to one side. The diagram (Fig. 2) shows how the tooth of an involute rack would cut its way through the rolling blank, thus forming one of the spaces between two teeth.

This is, in fact, the process by which this gear-cutter accomplishes its work. The cutting-tool represents one tooth of a rack pertaining to an interchangeable set of gears, and it obtains a reciprocating motion in the manner of a shaper-tool, while the blank receives a movement as though it were rolling on its pitch surface. In bevel-gears the tool representing the rack-tooth, while cutting, passes through the varying depths or pitches: therefore the straight line or involute rack-tooth is the only available one for this purpose. The tool, instead of running parallel with the pitch line, must run parallel with the bottom of the space. This will be more readily understood if it is considered that the rack of a bevel-gear is nothing else but a bevel-gear forming a pitch angle of 180° at the apex, or a flat, circular disk, with teeth converging from the circumference toward the center. The tool, in cutting, should follow the outline of the teeth of this imaginary plane-wheel: and it is evident, therefore, that only one side of the converging space can be formed correctly at a time.

The machine, then, consists of two principal parts—the shaper, which holds and operates the tool, and what may be called the evolver, which holds and moves the blank. In order that the blank shall imitate the movement of a rolling cone, the axis must, in the first place, be moved in the manner of a conical pendulum. To accomplish this, the bearing of the arbor which carries the blank is secured in an inclined position between two uprights to a semi-circular horizontal plate, which can be oscillated on a vertical axis passing through the apex of the blank. To complete the rolling action, the arbor must, in the second place, receive simultaneously the proper rotation, and this effect is produced in the machine by having a portion of a cone (corresponding with the pitch-cone of the blank) attached to the arbor, and held by two flexible steel bands stretched in opposite directions, thus preventing this cone from making any but a rolling motion when the arbor receives the before-described conical swinging motion. One end of each of the two bands, of course, is attached to the cone, while the other is attached to the framework of the evolver.

Mathematically speaking, a cone does not terminate at the apex, but is extended beyond, and thus consists of two opposite sides or surfaces meeting in the apex. Basing on this principle, the rolling cone above described is placed on the side of the apex opposite that on which the blank is placed, in order to avoid an interference with the tool.

The feed mechanism effects a slow intermittent movement of the semicircular plate which supports the inclined arbor, thereby producing a slowly progressing rolling of the blank while the reciprocating tool forces its way through the metal. The feed can be reversed or disengaged altogether, permitting the blank to be rolled to the one or the other side by a hand-crank.

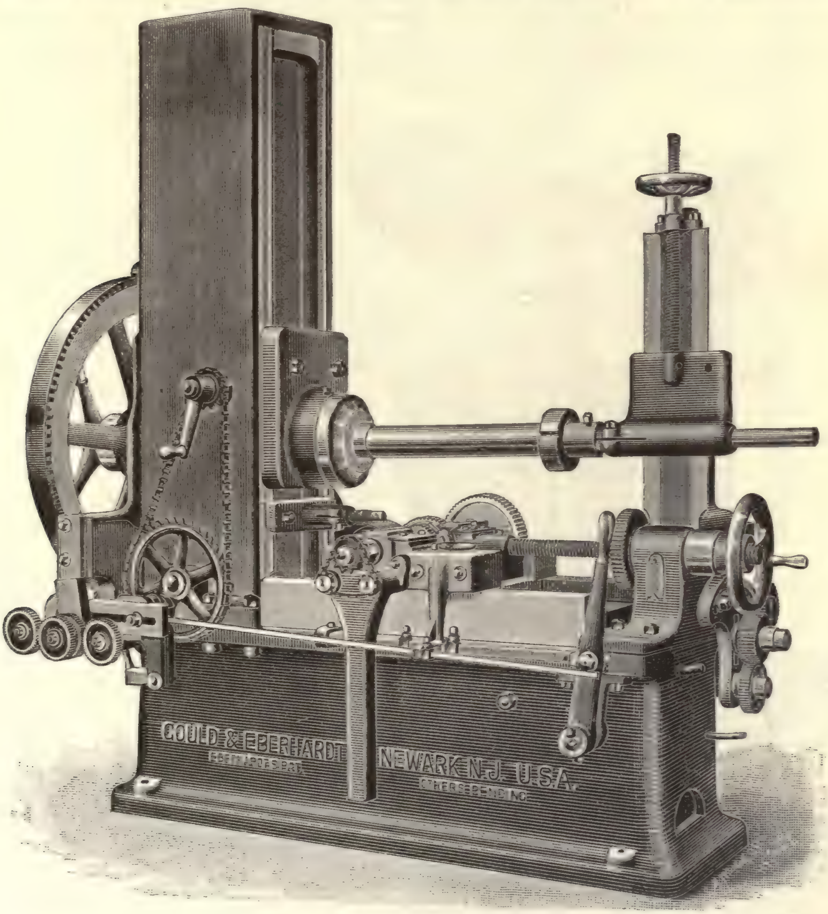


Fig. 4.—Automatic gear-cutter.

The arbor carrying the blank can be rotated independent of the rolling cone by means of a worm-wheel, worm and index plate, which enables the blank to be presented to the cutting device at properly spaced divisions corresponding with the number of teeth of the desired wheel.

It is essential that the tool should be so adjusted that the lowest point of the cutting side should move exactly toward the apex of the blank, and, in order to set the tool, a gauge is provided by which the tool can be adjusted. A distance-block is used between this gauge

and the tool; this mode admits of a high degree of accuracy, since variations of distances can readily be detected by the touch when the eye ceases to discern.

When a wheel is to be cut out of the solid, the tool is at first adjusted at a slight distance from its correct position, and after each cut the feed-motion of the evolver causes the blank to slowly roll, and allows the tool to cut out the stock in the manner shown in the diagram. All spaces are now treated in the same manner by using the index device, whereupon the tool is properly adjusted for one and then for the other side, each adjustment being followed by a repetition of the process in order to finish both sides of the teeth.

In securing the blank to the arbor, great care must be exercised in placing its apex exactly in the center of the evolver. A special device enables the operator to gauge the distance of the ends of the teeth from the center of the evolver, and whenever this distance agrees with that calculated from the drawing, the apex of the blank is in its right place.

The inclination of the arbor which holds the blank is made adjustable, so as to adapt it to the angle of the desired gear. This adjustment must be exactly concentric with the center of the evolver—i. e.. the apex of the blank. The rolling cone is made detachable, in order that it may be replaced by such cones as correspond with the angle of the blank to be cut; but as the number of cones required would be unlimited, means have been devised to make a limited number of cones suffice.

The tool consists of a triangular bar of hardened steel, forming at the point an angle of 30°, 15° on each side, and held by a special holder. By grinding, it can be more or less truncated to suit the pitch of the gear to be cut. By this form of tool a higher degree of accuracy is attainable than with tools having curved faces made to a gauge. The proper up-and-down and sidewise adjustment is effected by two slides working at right angles, and operated by screws. The clamp which fastens the tool-holder is so constructed that it also clamps the slides to the apron, securing the necessary stability. The box in which the apron works is made in parts, and the faces are turned true with the pin-holes, in order to get these faces exactly at right angles with the pin. The latter is fast in the apron, and revolves in the two sides, in which it has taper fits that the wear may be taken up. A device for lifting the apron during the return-stroke prevents the dragging of the tool.

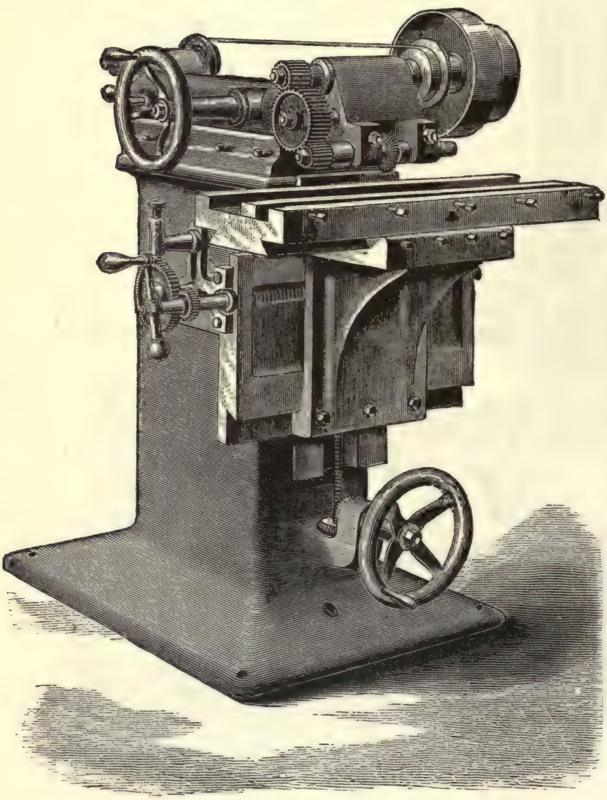


Fig. 5.—The Pratt & Whitney rack-cutting machine.

The tool-bar is moved by a Whitworth quick-return motion, which is attached directly to the belt-pulley. A double counter-shaft connected by cone-pulleys is employed to change the speed, if a shorter or longer stroke is desired.

Eberhardt's Automatic Gear-Cutter (Fig. 4) shows a machine for cutting spur-gears only, made by Gould & Eberhardt, Newark, N. J. It is designed to cut gears of a pitch as coarse as 3-in. and 20-in. face in steel, and is arranged so that two cutters, one blocking and one finishing, may be placed and run through together. The cutter-spindle has ample bearings on each side of the cutters. The wheels to be cut are held on the horizontal mandrel, which has a rigid outward support and bearing. The cutter is held by a spindle at right angles to the work-mandrel, on a slide which is fed automatically by the screw seen in the cut.

The Pratt & Whitney Rack-Cutting Machine, shown in Fig. 5, cuts the teeth of racks at any pitch, the spindle driving two cutters, which block out and finish teeth at the same time. Several racks may be cut at one time. The receiving-table has a vertical adjustment and a transverse horizontal traverse. The feed is automatic, with self-acting adjustable stop-motion. The cone is driven by a belt, and actuates the cutter-spindle through the medium of gears.

Swasey's Process for Generating and Cutting Spur-Gears.—A new process for generating and cutting the teeth of spur-wheels is thus described by Ambrose Swasey, of the firm of Warner & Swasey, Cleveland, O. (*Trans. A. S. M. E.*, vol. xii, 1891): "In the new process,

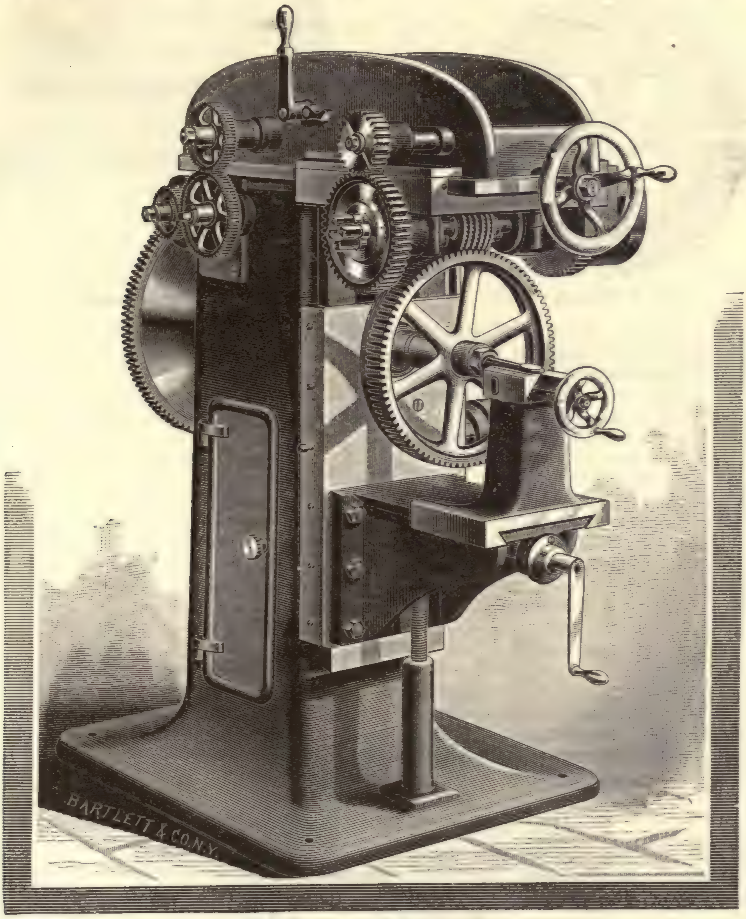


FIG. 6.—Swasey's gear-cutter.

instead of making all gears so that they will run into a rack, the rack is transformed into a cutting-tool, and by it the teeth of wheels of any diameter are generated and cut at the same time. Fig. 6 illustrates a gear generating and cutting engine constructed on this principle. The cutters are shown in position as they appear in the machine when the teeth are cut partly across the face of the wheel. The cutting-spindle and the main spindle which carries the wheel are connected by means of change-gears, the number of teeth to be cut in the wheel determining their proportion, on a similar principle as the change-gears of an engine-lathe, thereby causing the cutting-spindle to make as many revolutions as there are teeth required in the wheel, while the main spindle makes one revolution.

The cutting-tool is composed of a series of cutters rigidly connected, which revolve, and at the same time move longitudinally, or endwise, at right angles to the axis of the wheel to be cut; and at the same speed, it is continually revolving at the pitch-line, the motions being the same as in the case of a rack engaging with a revolving gear.

As it would be impracticable to continue moving the whole series of cutters endwise, they are bisected, and these segments are connected in series forming two sections, which revolve upon a common axis, and each section is given an independent endwise motion by means of a cam. When one section is engaged in cutting, it is carried endwise in the same direction and at the same velocity that the pitch-line of the wheel is revolving, until disengaged from it, when the cutters, while continuing to revolve, are carried back by the cam to their original position, ready for the next tooth. By means of both sections, as they continually revolve and alternately slide forward while cutting, and back when disengaged, there is a continuous cutting and generating process of the teeth in the revolving wheel. The head carrying the cutters is automatically fed across the face of the wheel, and when the cutters have proceeded once across the gear is completed.

Fig. 7 is a side elevation of a bisected cutter; and Fig. 8 shows a series of six cutters, the end one being in elevation and the others in cross-section—these having cutting portions,

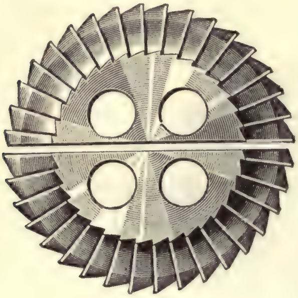


FIG. 7.—Cutter.

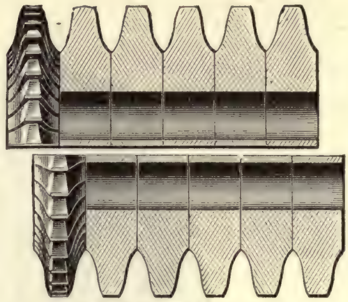


FIG. 8.—Set of cutters.

which in cross-section represent the teeth of a rack, with the addition to the diameter of a given proportion of the pitch by which the clearance and fillets at the bottom of the teeth are made. If their cutting portions are formed of cycloids, then the whole set of gear-wheels cut with them will be of the epicycloidal or double-curve system. If they are formed simply of straight sides, then a set of involute or single-curve gears will be generated and cut, or their cutting portions may be composed of both straight lines and cycloids and produce Prof. McCord's recent system of gearing, which has composite teeth with the contours partly involute and partly epicycloidal.

All the cutters in a series are made exactly alike and interchangeable, the thickness of each or the distance from the center of one to the center of that adjoining being equal to the pitch of the gear to be cut. As indicated in Fig. 7, the two segments of a cutter are first made whole, with four holes an equal distance from the center, through which the rods pass that fasten them together. After the cutters are nearly completed they are bisected with a narrow tool, leaving two holes in each segment.

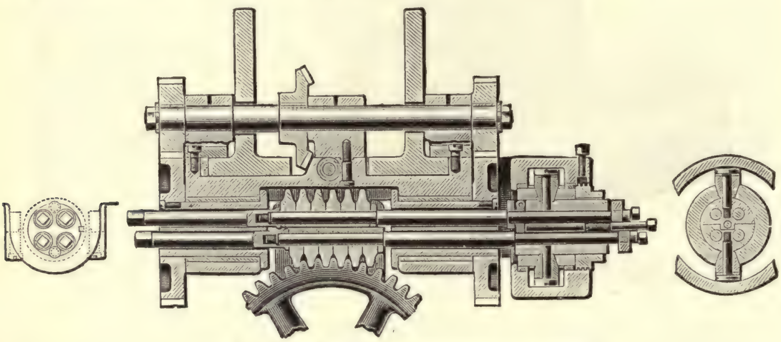


FIG. 9.—Swasey's gear-cutter—section of head.

Fig. 9 is a cross-section of the head, showing the mechanism for revolving and reciprocating the cutters. The rods which extend through the cutters serve not only to hold them firmly together but to revolve them, and at the same time act as slides for the reciprocating motion. The spindles on either side of the cutters, through which the rods extend, are revolved independently and at the same speed by means of a parallel shaft, having a pinion at each end, which engages with a large gear on each spindle. By this means the four rods carrying the two cutter sections are revolved from each end, thus avoiding the torsional strain which would result if driven from one end only. The pair of rods for each section, after passing through one of the spindles, terminates in semi-cylindrical blocks. From each of these blocks a stud extends, on which is journaled a roll, engaging with a cam attached rigidly to the head. This cam is shown in Fig. 10, the working portions being made in the form of a screw-thread, which, if extended all the way around, would have a lead equal to the thickness or pitch of the cutter. As each section of the cutters engages with the wheel but three fourths of a revolution, the thread portion of the cam which carries the cutters forward extends only three fourths of its circumference, leaving the other one fourth for the reverse curves of the cam to bring the cutters back to their starting-point. Provision is made for adjusting one section of the cut-

FIG. 10.—Cam.

ters so as exactly to coincide with the other. The variation in the spacing from one tooth to another is reduced to a minimum, as the series of cutters act upon both sides of a number of teeth at the same time, and serve to average and eliminate any local inaccuracies in the division of the index and driving-gears; also to obviate any tendency to crowd the wheel from one side to the other.

The endwise motion of the cutters and the revolving of the wheel at the pitch-line being exactly the same, the process of generating and cutting the teeth goes on continuously and uniformly around its entire periphery, so that one part is not heated more than another, but all the teeth are cut under exactly the same conditions, and when the revolving cutters have once passed across the face all the teeth in the gear are completed and given the correct form for each diameter of wheel; and as by the Willis theory all gears are cut to run into a rack, so by this process the Sang theory is put into practice and a rack is made to cut correctly all gears.

Gear-Cutter: see Watches and Clocks.

Gears: see Carriages and Wagons.

Gin, Cotton: see Cotton-Gin.

Glassing-Machine: see Leather-Working Machinery.

GLASS-MAKING. *The Siemens Continuous Tank-Furnace.*—The use of the melting-pots in glass-making is now altogether abandoned, and the batch is introduced into, melted in, and worked from a tank occupying the entire bed of the furnace, which latter is heated by the well-known Siemens regenerative gas system. Two floating bridges or partitions divide the tank into three compartments—the melting compartment, the refining compartment, and the working-out compartment. In the illustration, Fig. 1 is a longitudinal section of the furnace, and Fig. 2 is a transverse section taken through the melting compartment looking toward the rear of the furnace. The raw material (or batch) is fed into the melting compartment through the door at the back end of the furnace, and the partially melted glass passes under the floating bridge into the refining compartment, where the metal, by the influence of the higher temperature maintained upon its surface, is completely purified, and sinks to flow under the other bridge into the working-out compartment in a thorough workable condition. Air-passages are provided to maintain the sides of the tank at the requisite temperature to prevent any egress of glass through them, and the floating bridges are renewed as often as they become burned out. The flames play across the furnace from the gas and air ports, which lead to the regenerators of the regenerative gas-furnace. In order to regulate the temperature of the different parts according to the various stages of preparation of the glass in the several compartments, the gas and air ports are constructed of larger or smaller dimensions, or their number varied according to the amount of heat required at the different points. This is also facilitated by means of division walls (not shown in the illustrations), which may be built over the floating bridges to separate the compartments. The temperature of the working-out compartment is further controlled by regulating the draft of the furnace chimney, by diminishing which more or less flame must necessarily pass over the bridge into this compartment from the refining compartment.

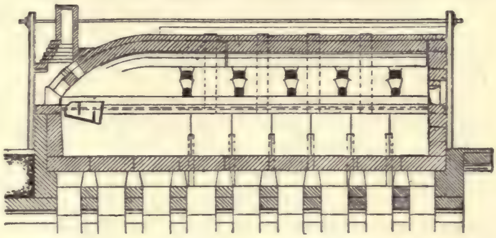


Fig. 1.—Siemens tank-furnace.

About the first improvement made on the Siemens continuous tank-furnace just described was the idea of Mr. Frederick Siemens to construct the tank in the form of a horseshoe or segment of a circle, with the feeding-door and communications to and from the regulator arranged on the flat side of the segment, for the purpose of cooling the exterior surface of the tank and rendering it available for working-out holes. He also arranged a series of working-out compartments on the inner side of the curvilinear wall, each compartment communicating by means of a passage with the melting-chambers. In the continuous refining and working-out of glass it also became necessary to remove or avoid the impurities which were found to float upon the surface of the liquid in the tank or pot, and therefore Dr. Siemens contrived a device to do that important work in a simple and inexpensive way. He constructed a fire-clay vessel or boat of oblong shape to swim in the liquid glass contained in the tank, and this boat was perforated below its draft-line so that, as it floats, the melted material flows into the boat through these holes entirely free from the im-

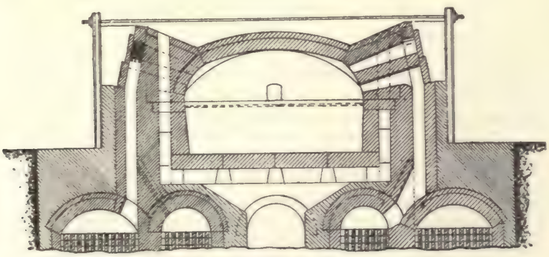


Fig. 2.—Siemens tank-furnace.

purities floating on the surface of the liquid in the tank or pot. To further assist the process of fining and working-out of the glass, the boat is made in two compartments, the second of which is the working-out compartment: the dividing partition is provided with apertures near its bottom, so that, as the glass flows into the boat free from impurities, as above described, it becomes more fluid in the first compartment by the action of the heat upon its surface than below, and consequently, in becoming denser, it sinks to the bottom of this first compartment, whence it flows through the apertures named into the second compartment, which is within convenient reach of the working-out hole of the furnace.

It had been observed that, in this glass-melting process, the metal as it "fines" sinks below the surface, and that, consequently, in order to work out the metal to the best advantage, the depth of the tank had to be very considerably increased, so that below the fluid-molten metal there should be a layer of metal in a semi-fluid or partially solid condition lining the tank. One of the later glass-making patents to Frederick Siemens covered this important point. He uses a deep tank, in which there are boats or floating fining-vessels made of refractory material, and provided with projecting horns which serve as fenders to keep them from close contact with the sides of the tank.

Another improvement upon the regenerative tank-furnace for continuously melting glass consisted in placing the regenerators at the sides of the tank and forming an open cave below the tank, communicating with air-spaces on each side, for the purpose of cooling the bottom and sides and receiving such metal as may leak through in any open accessible space.

A patent was also granted in 1885 for an improvement in the art of subjecting a charge in a glass-melting tank to the gradual application of heat, consisting of treating such charge in a tank so arranged and adapted that the surface of the molten metal contained therein shall be preserved constantly level, and having a bottom wholly or partially inclined from the charging end toward the gathering end, whereby said charge, when melted, becomes of varying depth above said bottom and below the hot gases forming the source of heat. It is claimed for this invention that the heat can be applied more uniformly to the charge or batch, and the latter becomes more thoroughly fluxed, preventing also the formation of deposits in the tank, or what are technically known as "cords" or "stones."

Tank-furnaces are used principally in bottle-works and in the manufacture of rolled plate, but window-glass of a low grade has also been shown as made in one of these tank-furnaces. In some instances they are fired by common coal from one end, the working-holes being on the other three sides. A new practice, which was introduced in France some few years ago by M. Clemandot, a celebrated glass manufacturer, has found much favor among glass-makers. It is the coating with nickel of molds, blow-pipes, and tools used in glass-blowing. This coating prevents the oxide of iron from being introduced into the glass from impure cullets.

Cutting Glass.—Several attempts have been made to cut glass by machinery, but up to within a few years no considerable amount of success has been met with. There was a machine in operation at the Paris Exposition which had just been brought out, and was supposed to be for cutting several tumblers at a time, although only single glasses were cut in public. The tumbler was mounted upon a holder pressing upon the face of a horizontally revolving wheel, the holder being weighted sufficiently to give the proper pressure to grind out the flutes. The apparatus was automatic, raising and revolving the tumbler a sufficient distance to cut the next flute, and again lowering it against the grinding-wheel, repeating the operation until all the flutes around the tumbler are cut. There does not appear to have been any means for regulating the penetration of the grinding-wheel, pressure being simply depended upon for action.

An American glass-cutting machine, invented by Messrs. Charles & J. P. Colné, has been used for some years in the successful cutting of decanters, goblets, sugar-bowls, mustard-pots, tumblers, etc. It is not entirely automatic, but is adapted to cut all geometrical shapes and patterns, as well as a great variety of styles of cutting. The rapidity, the regularity, and the perfection of the work done with this machine insure considerable saving in the original cost price of cut articles.

Pressing or Molding Glass.—When pressing glass continuously for a long time the molds often get heated too high, and in this state glass is very apt to stick to them. This inconvenience is now done away with by a system of blowing air into the molds. By means of a revolving fan or other device, and tin pipes arranged around the furnace, a continuous stream of air is furnished. India-rubber pipes are attached to the tin pipes at suitable places. By means of these pipes, after each pressing, or as often as necessary, a stream of air is sent inside of the mold, thereby cooling it. The air circulating in the pipes may also be used for ventilation and for cooling the glass-house. Of late, attempts have been made to use presses for pressing glass by steam or compressed air. One of these presses has a set of molds carried upon a revolving bed, and is operated by a presser like a hand-press. The power, however, is applied to the presser by means of an auxiliary steam-engine, which is continually at work. Whenever an article is to be pressed, by suitable leverage the presser is forced down, then released; the bed-plate revolves far enough to bring another mold under the presser, and the operation is repeated as often as desired. Mechanism is attached and operated also by steam so as to push the pieces out of the mold after they are pressed. These are the principal features of the invention.

In the other press steam is replaced by compressed air contained in a reservoir, which may be filled by means of an air-compressing engine. The bed-plate carrying the molds has a rectilinear motion. When an article is to be pressed the mold is brought under the presser; by means of suitable valves and pipes air is sent to a cylinder-piston carrying the plunger.

The pressure of the air forces the presser down into the mold, the valves are reversed, and the piston and presser fly back. A new mold is now under the plunger. The operation may be repeated as often as desired by simply opening and closing the air-valves. In this press, as in the other, the pieces are forced out of the molds by rising plugs or bottoms. The different motions of this press are entirely automatic, with the exception of operating the air-valves. In order to form the air-bubbles which are often seen inside of solid pieces of glass, they have been pressed with cavities on the outside, and after being reheated they are closed by pressing the outside down with suitable tools, thus inclosing the air in the cavities.

Rolling Plate-Glass.—A new method and apparatus for rolling plate and sheet glass has been introduced by Mr. James W. Bonta, of Wayne, Pa. The main features of the operation are: first, rolling the glass plate on one side, then placing it between platens, then raising both platens, then rotating the same, then lifting one of said platens, and then rolling the other side of the plate. The machine for accomplishing this work has combined with a presser roller a movable platen for passing the glass underneath this roller, and a vertically sliding frame having journals which carry the second platen. There are special devices for bringing the platens together and locking their journals, and for raising, lowering, and rotating the locked platens, as well as for releasing the latter with the unrolled side of the glass uppermost, so that it may be ready for the next part of the operation.

Gold-Mill: see Mills, Gold.

GOVERNORS. We present a variety of the latest improved types of governors.

Ball's Shaft-Governor.—Mr. Frank H. Ball has recently made a new application of a dash-pot to centrifugal governors, which seems to be free from the difficulty formerly encountered with dash-pots in this connection. It is thus described in *Trans. A. S. M. E.*, vol. ix:

"The principles involved may be understood by reference to Fig. 1. The governor here shown is one of the ordinary forms of shifting eccentric governors. The introduction of the spring S between the dash-pot and the movable part of the governor is the new feature. Its operation and effect are as follows: Suppose the long spring D be drawn up until its initial tension, in distance of stretch, shall correspond exactly with the distance between the center of gravity of the weight and the axis of revolution. This is what is called 'full theoretic tension.' The condition is the same as would be obtained if the weights were first placed at the center of the shaft, and after attaching the spring without any tension the weight was then moved out to the position shown. With this relation between the position of the weight and the tension of the spring, the increase and decrease of centrifugal force caused by moving the weight to or from the axis of revolution would exactly harmonize with the changes of resistance of the spring due to said motion; and if the two forces were in equilibrium in one position, they would be so in every position at the same speed. This condition, as has already been said, should be expected to give uniform speed of the engine at every position of the governor, but has been found impracticable on account of its instability. The object of the dash-pot and spring here shown is to allow the theoretically perfect adjustment of the long spring, and to furnish ample stability without making the governor sluggish, or in the least preventing a quick and delicate balancing of the forces. This spring S is arranged for both compression and extension, and has a range of deflection sufficient to allow the full motion of the governor, from one extreme to the other, without regard to the motion of the piston of the dash-pot to which it is attached. The resistance of this spring S, having no initial tension, is entirely out of harmony with the other spring, and combined with them produces exactly the effect when motion takes place that is obtained ordinarily in centrifugal governors, by using springs with less than the full theoretic tension; and if the dash-pot piston should remain stationary, the same change of speed would be found between the extreme positions of the governor; but by reason of the movement of this piston, the tension on spring S is released, and it then ceases to be a factor in the speed, which is only the result of the long spring, and, as has been previously shown, it must be the same at every position of the weight. This theory, though somewhat obscure, seems to be correct, and its practical operation under careful tests proves it to be so."

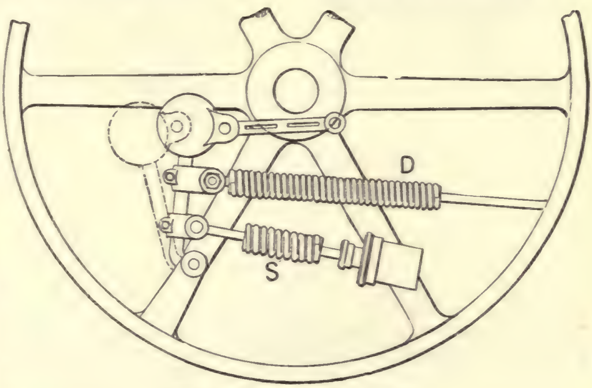


FIG. 1.—Ball's shaft-governor.

Governors are now made of various types, embodying this principle, and have been found to compel the same number of revolutions per min. of the engine under any condition of load or boiler-pressure within the full capacity of the engine.

Smith's Governor is shown in Figs. 2 and 3. It is described at length in *Trans. A. S. M. E.*, vol. xi. It was designed on the basis of the following propositions: First, a governor to

be sensitive must be as free as possible of friction. Second, to be powerful, the forces which are in equilibrium must be large compared with the resistance of the valve to be moved.

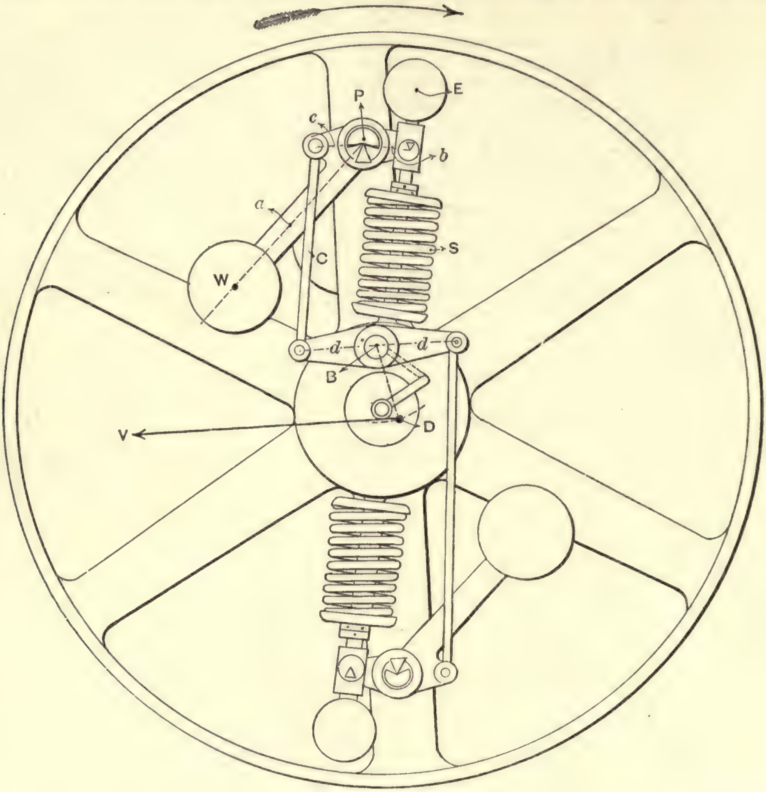


FIG. 2.—Smith's governor.

Third, in order that the shaft may not be thrown out of balance by change of position of the governor-weights, these weights must be symmetrical. Fourth, that the engine may make long runs the joints of the governor must be so constructed as not to require oil, or be capable of lubrication while in motion.

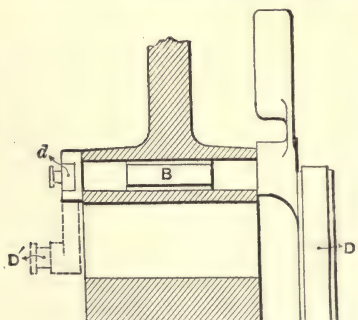


FIG. 3.—Smith's governor—section.

This governor was designed in 1883, and has been applied to a number of engines with unbalanced as well as balanced valves. A small shaft B is journaled in the hub of the fly-wheel, and is parallel to the main shaft. The eccentric, whose center is at D, is fixed to one end of the shaft B, and the cross-arm d to the other. The center of the eccentric may thus move about B, across the shaft, and produce the variable valve-motion. Each end of the cross-arm d is connected by a link C to an arm c, pivoted at P. The flying-weight W fixed to the arm a, also pivoted at P, tends to move outward as the speed increases. It is resisted by a weight E acting on the arm b, also pivoted at P, which moves inward when W moves outward. The spring S, whose axis is radial, also acts on arm b, and assists the weight E to urge W inward. The valve resistance V also assists the weight E. The arms a b c are all formed in one piece. The weights W and E and spring S move as nearly as possible upon radii from the center of rotation. For the purpose of reducing the friction to a minimum, the pivot P, which sustains the greatest strain, and the bearings at the ends of arms b, are made in the form of knife-edges of hardened steel. They require little or no oil, and are inclosed so as not to gather dust. The joints of the links C support little strain, and are usually made simple pin connections. The eccentric being mounted on the small shaft B, which has a long bearing in the hub of the fly-wheel, requires

little force to move it. The shaft B may, besides, be oiled while the engine is running, by means of a small pipe extending from the center of the main shaft to the middle of shaft B, so that the friction here is also reduced to a very small amount. This governor is readily adapted to run in either direction. The spring has only to take up the difference of centrifugal force of the weight W in its inner and outer positions, instead of the whole of that force, as in most governors. The spring may therefore be small and short, and still not be strained to such an extent as to fatigue the metal. A common compression-spring, such as is in use under cars, has been employed, and found simple and effective. If a spring breaks, the engine stops. The initial tension of the spring, which is what supplies the greater part of the centripetal force in most governors, is here replaced by the centrifugal force of the weight E, which force is practically constant within the range of speed variation. A variation of speed of less than 1 per cent between no load and 0·7 cut-off may be readily obtained in practice, and this regulation can be maintained during long-continued runs. When this governor is applied to center-crank engines with valve connections outside of the fly-wheel the eccentric can be dispensed with, and replaced by a wrist-pin D' formed on the end of an arm extending from the cross-arm d, as shown in dotted lines to the left of Fig. 3.

FIG. 4.—Rice governor.

The Rice Automatic Engine-Governor is shown in Fig. 4. It consists of two balls hung on pivots, and held in equilibrium against centrifugal force by two elliptic springs, whose tension may be increased or diminished by the tension-bolt which connects them. The balls are connected to a lever, which in its turn is connected with the eccentric through the hollow crank-pin. The balls are cast hollow, and may be loaded with shot. (See ENGINES, STEAM STATIONARY RECIPROCATING, for the Rice engine.)

The McIntosh & Seymour Governor.—Fig. 5 represents the governor used on the McIntosh & Seymour engines (see ENGINES, STEAM STATIONARY RECIPROCATING) up to 150 horse-power with the weights in their two extreme positions, the details of the different parts being shown in Fig. 6. In common with other so-called shaft-governors, it is a device

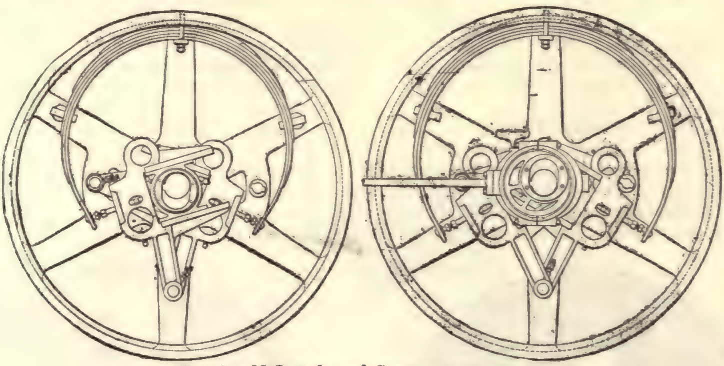


FIG. 5.—McIntosh and Seymour governor.

for regulating the speed of the engine by centrifugal weights and opposing springs, which control the point of cut-off by swinging the eccentric across the shaft. The centrifugal weights are pivoted, and are provided with inclined jaws. When the weights move, the inclined jaws acting through the blocks (which slide in them and turn on a boss on the pendulum) change the position of the pendulum. This may be termed a wedging action, and though the slightest force acting on the weights is sufficient to affect the position of the pendulum, the reverse is not true, and the weights are undisturbed by the effort of the valve-gear on the pendulum. The freedom from friction of the governor is due principally to the use of a plate-spring opposing the centrifugal force of each weight and acting through a steel pin, hardened and resting in hardened

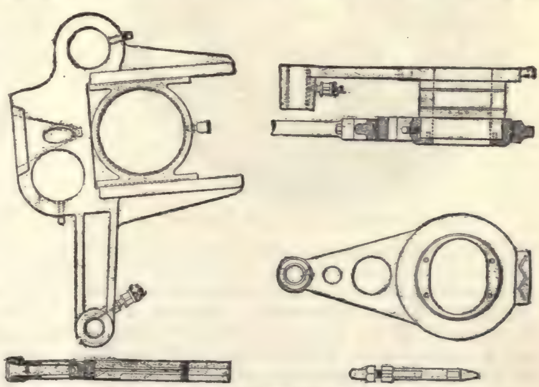


FIG. 6.—McIntosh and Seymour governor—details.

steel cup sat both ends. The cup in the weight is situated at the center of gravity, so that the centrifugal force is directly resisted by the spring in a frictionless manner. The double spring will keep the tension on the weights equal, notwithstanding any slight inequality in the adjustment of the length of the pins. Since the two weights move together in an opposite direction, they are in statical equilibrium in all positions. The pressure of the valve-gear transmitted through the pendulum and blocks is transferred several times during each revolution between the opposite jaws of each weight. This action is important, since it affords every opportunity for a most delicate balancing of the centrifugal force and opposing resistance of the spring.

The speed of the engine can be changed, if it is desired, by adding to or taking from the weight of the centrifugal weights.

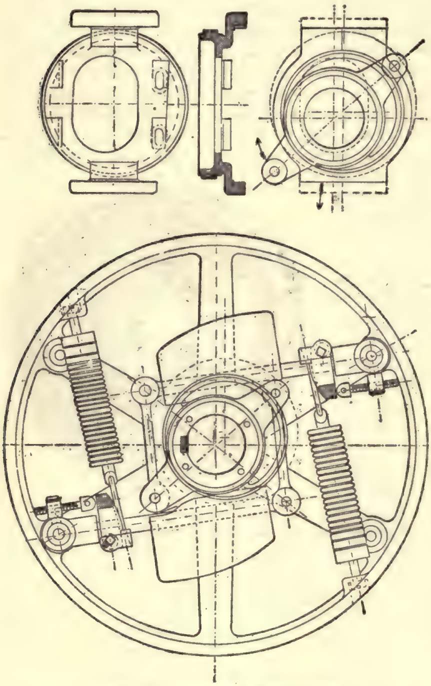


FIG. 7.—Giddings governor.

The Giddings Governor, shown in Fig. 7, consists of two eccentrics; the auxiliary eccentric rotating on the hub of the governor-disk by the usual system of weight-arms and levers as shown. This eccentric has a cross-head strap which gives a motion square across the shaft, preserving a constant lead. The main eccentric, as shown, fits over this cross-head by means of lugs, and its throw is varied by the movements of the same, thereby changing the travel of the valve to give the required port-opening for varying loads and boiler-pressures, at the same time preserving uniformity of motion. This combination of two eccentrics gives great stability, as it is mechanically locked in every position.

The Armington & Sims Automatic Cut-off Regulator (Figs. 8 and 9) consists of a wheel which is fixed to the engine-shaft, to which are hinged the weights 1 1; these weights are controlled by springs, one end of the same being seated in a pocket fixed on the spoke of the wheel, or in some cases attached directly to the rim of the wheel. The inner eccentric, marked *C*, having ears attached, is placed close to the regulator-wheel, and is free to turn upon the shaft. From the ears rods (2 2) are connected with the regular weights. On the outside of the inner eccentric, and free to turn, is placed an eccentric ring *D*, from which a rod (3) is connected to the toe of one of the weights. On this outer eccentric ring are the

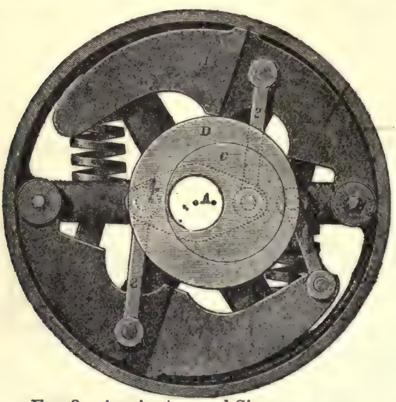


FIG. 8.—Armington and Sims governor.

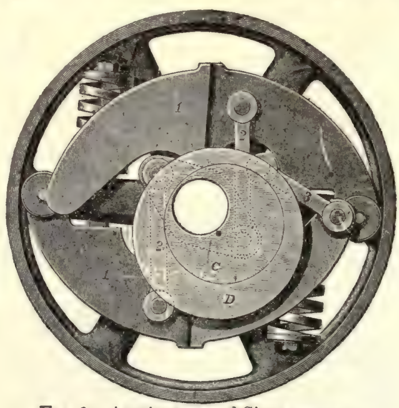


FIG. 9.—Armington and Sims governor.

usual eccentric straps, to which are directly attached the valve-rod. When the engine is running at its greatest velocity, the weights, due to the centrifugal force overcoming the springs, will be out. The eccentricity of the two combined eccentrics is then the distance shown at *A*, in Fig. 8. The other extreme, when the engine has its greatest load requiring later cut-off, the position of the weights will be as shown in Fig. 9. It will be seen that when the weights are in such position, the inner eccentric has been moved back, and the outer eccentric forward or in the opposite direction, and the eccentricity by this combined movement is increased. This is sufficient to allow the steam to follow the piston to about seven tenths of the entire

stroke. This wide range from the simple lead of valve, as shown at *A*, causes extreme sensitiveness of the regulator. The lead in all positions of the eccentrics remains constant and is practically unchanged.

The Woodbury Engine-Governor (Fig. 10) is of that class in which the point of cut-off or valve-closure is effected by moving the eccentric across the shaft, thereby varying the length of the valve travel. The movement of the eccentric is operated by centrifugal weights, the centripetal or opposing force being furnished by a single spiral spring. Fig. 10 is a side elevation of the governor. The weight *A* is bolted to the eccentric arm, and is therefore pivoted to the fly-wheel at *B*, the same point as the eccentric itself. The weight *A′* is adjustable on the lever *D*, which is pivoted to the fly-wheel at *B′*, and connected to eccentric *C* through the link *E*. Rubber buffers (not shown) at point *a* and point *b* form stops for the extreme inward position of the weights, and the one at *c* for the extreme outward position. In the position shown, the weights are at their extreme inward point of movement, the center of eccentric being at *d*, and corresponding to point of cut-off by the valve at $\frac{3}{4}$ stroke. In the extreme outward position of the weights the center of the eccentric is moved to *e*, where the eccentric gives to the valve its least travel, the point of closure or cut-off being at zero. (See ENGINES, STEAM STATIONARY RECIPROCATING, for the Woodbury engine.)

FIG. 10.—Woodbury engine-governor.

GOVERNORS, PUMP. *The Albany Steam Trap Co.'s Pump-Governor* is shown in Figs. 1 and 2. Fig. 2, in section, represents a closed vessel containing one within it, which is termed a movable bucket, having screwed into its bottom a short piece of pipe which serves as a guide for the same as it rises and falls, and also as an exit-pipe to allow the water to pass from the bucket on its way to the pump. On the upper side of the governor is a slide-valve for supplying the pump with steam; this valve is in a small steam-chest into which the steam from the boiler is first introduced. The face on which this valve slides contains three ports, two of them being in connection with each other and leading thence into the chamber to which the steam-pipe is connected that conveys the steam to operate the pump, while the other port is smaller than the two just mentioned. When the bucket is at its highest position the valve will be at its extreme point to the right, closing the first two ports and leaving the third one open to a passage under the valve from the interior of the governor to the atmosphere. The valve is caused to move over the ports by the rising and falling of the bucket through the intervention of a bell-crank lever. The operation is as follows: The space between the bucket and outer case must first be filled with water by the water running in from the system of heating-pipes; the valve, however, that admits the steam to the steam-chest must first be closed until this space is once filled, for the condition of the apparatus is such that when there is no water in this space the bucket will be necessarily in its lowest position, and consequently the two ports for admitting steam to the pump will be wide open, and the pump will at once commence racing, since there will be no water present for the pump to act on. This space having been filled with water, and the bucket in its highest position, the two steam-ports being closed, and the pump at a state of rest, the introduction of the water of condensation through the check-valve in the receiving-pipe shown on the left-hand side of the governor, flowing over into the bucket, will cause it to descend when it has received within it a sufficient quantity of water to overcome the floating power of the water surrounding it; in descending it will, through the intervention of the bell-crank lever, cause the slide-valve to be moved toward the left, opening thereby the steam-ports for admitting the passage of the steam from the steam-chest to the pump, which will start the

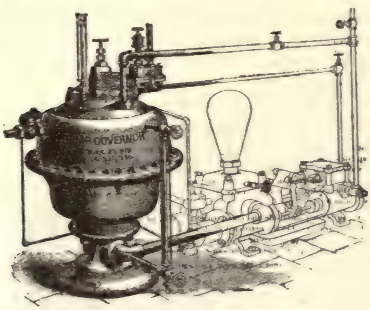


FIG. 1.—Albany pump-governor.

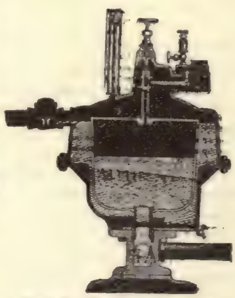


FIG. 2.—Pump-governor.

pump in operation. If the pump is of a capacity greater than the supply it will, after a few strokes, take water from the bucket enough to so lessen its weight that the surrounding water will float it upward and cause the slide-valve to move to the right, thus closing the steam-ports and stopping the pump's operation until a sufficient amount of the water of condensation shall have been received anew into the bucket to cause it to descend and again operate the pump. This operation continues on repeating itself.

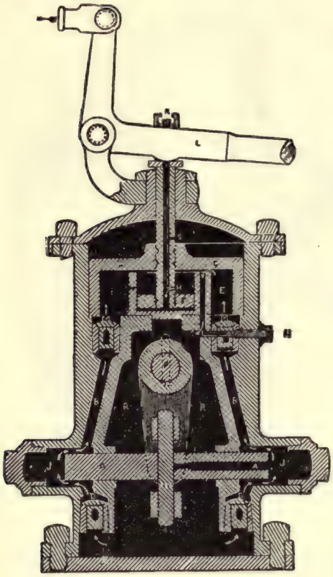


FIG. 3.—Mason pump-governor.

The Mason Steam-Pump Governor is shown in Fig. 3. It is attached directly to the piston-rod of the pump and operates a balanced valve placed in the steam-pipe, thereby adjusting the amount of steam to the needs of the pump. It consists mainly of a cylindrical shell, or reservoir, filled with oil or glycerine. The plunger $A\ A$ is connected through the arm I to some reciprocating part of the pump or engine, and works horizontally and in unison with the strokes of the pump, thereby drawing the oil up through the check-valves $D\ D$ into the chambers $J\ J$, whence it is forced alternately through the passages $B\ B$, through another set of check-valves $M\ M$, into the pressure-chamber $E\ E$. The oil then returns through the orifice C, the size of which is controlled by a key inserted at N, into the lower chamber, to be repumped as before. In case the pump or engine works more rapidly than is intended, the oil is pumped into the chamber $E\ E$ faster than it can run through the outlet at C, and the piston $G\ G$ is forced upward, raising the lever L with its weight and throttling the steam. In case the pump runs slower than is intended, the reverse action takes place, the weight on the end of the lever L forces the piston $G\ G$ down, and more steam is let on. As the orifice at C can be increased or diminished at the will of the engineer, it will be seen that the action of every portion of each stroke can be controlled. The secondary chamber H also fills with oil and acts as a cushion, preventing the main piston $G\ G$ from dropping too suddenly or fluctuating.

The Fisher Steam-Pump Governor, made by the Fisher Governor Co., of Marshalltown, Iowa, is shown in Fig. 4. The valve in the main shell is a double one, the upper disk being the largest, so that there is always an upward pressure on the valve-stem. The upper wheel on the valve-stem in yoke is simply for a lock-nut; the lower one is fastened in place by a small lock-nut below it, and by turning this wheel to the right the valve-stem is screwed up into the bottom of the piston-rod, which raises the valve and admits the steam to the steam-chest of the pump. Above the yoke there is a brass cylinder in which is a piston with an ordinary cup leather-packing, which piston rests upon a steel coil-spring. At the top of the pipe-work over the governor is a small globe-valve, and from this point a ¼-in. pipe is taken to and connected with the discharge-pipe from the pump, which brings the water-pressure from the pipes or mains on to the top of the piston. If the valve is raised by the hand-wheel until the pump has brought the pressure in the pipes or mains to the point desired, and the upper wheel or disk is then set up tight—as a lock-nut—against the bottom end of the piston-rod, the governor will hold the pressure uniform at the point set. The small angle-valve is for a relief-valve, to relieve the pressure between the piston-head and globe-valve above, when the globe-valve is closed. The small down pipe is to carry off any drip or waste. The whole device is intended to be placed in the steam-pipe between the steam-chest and throttle-valve, and as close to the steam-chest as possible. When the water-pressure falls below the point set, by the opening of a valve, or hydrant, or an automatic sprinkler-head, or in any way, the pressure being less on the piston, the steam raises the valve, gradually increases the speed of the pump, and maintains the pressure at the point desired; and when the water is not being used the increased pressure on the piston gradually forces the valve to its seat, which stops the pump until the pressure falls again.

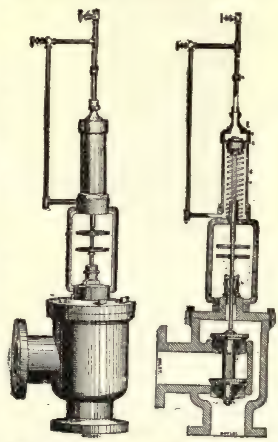


FIG. 4.—Fisher pump-governor.

Grain-Elevator: see Elevators. **Grain-Mills**: see Milling-Machines, Grain.

Grate: see Boilers, Steam.

GRINDING, EMERY. *Qualities desired in Emery-Wheels.*—In a lecture on the subject of emery-wheels, delivered by Mr. T. Dunkin Paret, President of the Tanite Co., before the Franklin Institute, and printed in the *Journal of the Institute* for March, 1890, he sums up the necessary qualities as follows: "Such a wheel must have tenacity to withstand the

centrifugal strain generated by its revolution at the speed of from ¾ to 1¾ mile per min. Its ability to resist heat must be great, inasmuch as the friction of grinding rapidly raises the metal being ground to a red and even an almost white heat. It follows, from the above facts, that the proper base for a perfect wheel should be some organic substance, either vegetable or animal."

Experiments with Emery-Wheels.—Mr. Paret, in the lecture above referred to, says: "To obtain the maximum result from any emery-wheel, it must be perfectly round, perfectly centered, must be run at a high rate of speed, and be so solidly mounted and so free from adhering metal as to allow of continuous contact between work and wheel. With equal speed and proportional pressure a wheel 6 in. thick ought to cut off six times as much metal from a bar 6 in. wide as a wheel 1 in. thick would from a 1-in. bar.

"Experiments were made with only one make of wheel, the size being about 14 × 1¾ in. In comparing the cost of various processes, the same rate for labor was charged against wheel, file, and cold chisel. Charging a moderate price for the wheel (33⅓ per cent discount from list), the maximum cost of grinding off 1 lb. of cast iron was 11·6 cents. Charging a low price (60 per cent discount from list), the minimum cost was 2·4 cents. The cost per lb. of filing off cast iron was 35·9 cents. In one half hour's steady work the emery-wheel removed 17 lbs. of brass, the cold chisel 1 lb. 4½ ozs., and the file only 8 ozs. The wheel removed 7 lbs. 12 ozs. of cast iron, the cold chisel 2 lbs. 5½ ozs., and the file only 5¾ ozs. The wheel removed 2 lbs. 8 ozs. of wrought iron, the cold chisel 10½ ozs., and the file 2¾ ozs. The wheel removed 3 lbs. 7 ozs. of saw-steel, the cold chisel 1½ oz., and the file only 1 oz. The soft metal (brass) clogged the file and reduced its cut, so that the wheel removed 34 times as much as the file did. The hard saw-steel resisted the file so that the wheel removed 55 times as much as the file did. Cast iron, which neither clogged much nor resisted greatly, gave the file greater play, and the wheel only removed about 21 times as much as the file. In all these experiments the work was forced against the wheel by hand, and such experiments gave but uncertain results, owing to the inequality of pressure and to the personal factor. Fatigue, strength, skill, prejudice—all might affect the results.

"Every wheel which tends to glaze badly with metal is dangerous as compared with one which does not glaze. Every free-wearing wheel is comparatively safe. He who wants safe wheels should avoid all that glaze quickly. He should use large flanges with very thin wheels. He should have mandrel-holes of moderate size and very slightly larger than the spindle. He should mount the wheels substantially. And still, to be absolutely safe, he may add coverings and guards, provided these are not of cast iron, but are of wrought iron, boiler-plate, or tough steel. Another established point is that, as a general rule, increased wear of wheel indicates increased product in the amount of metal ground. It is a nice point (yet to be decided by the invention and long use of a competent test machine) just how far wheel consumption and metal removal are proportionate. The careful observations thus far made seem to indicate that there is a reasonable average maximum removal of metal compatible with economical consumption of wheel material; that if, by increased speed or pressure, the wheel is made to wear out faster than this, more metal can be removed, but that the gain in metal removal is far more than balanced by the increased loss of wheel material."

Competitive Trials of Emery-Wheels.—A commission of experts, consisting of Dr. Coleman Sellers, Prof. J. E. Denton, and Alfred R. Wolff, in 1889 and 1890, made, on behalf of the Tanite Co., an extensive investigation into the relative merits of the emery-wheels made by fifteen different manufacturers in the United States. From the preliminary report of this commission, made in 1891, it appears that of the fifteen varieties six were found too unsafe to warrant their general use, 57 per cent of the wheels bursting under the same conditions which other wheels passed through uninjured. Eleven varieties (among which are included the six unsafe varieties) were found to be such slow cutters that the average metal removal of ten of them was less than the general average of all the wheels. Of the fifteen varieties, only four were found to be rapid cutters. Of these, one wore so rapidly that the cost of its rapid cut was unreasonable. This left three safe, effective, and satisfactory wheels, one of which, however, was demonstrated to work at a greater cost than the others. The rivalry was thus narrowed to two wheels, but, in the judgment of the board, further trials are still necessary before the relative values can be determined.

Grinding-Lathe: see Lathes, Metal-Working. **Grinding-Machine, Saw**: see Saws, Metal-Working. **Grinding Machinery, Ore**: see Ore-Crushing Machines.

GRINDING-MACHINES. *The Sellers Drill-Grinding Machine* is represented in Fig. 1, with a drill in place ready to be ground. The drill is carried in a holder which is pivoted to the top of the main upright. The adjustment of the drill to any required angle of point between 90° and 130° of included angle is effected by swinging this holder about its center. The lips of the drill are chucked by two jaws, which are opened and closed by the hand-wheel *A*. The back end of the drill is steadied by an adjustable center-stop *B*. This stop is made reversible, being provided with a male center at one end and a female center at the other, the latter to be used with the small drills having no center-holes in their ends. The grinding-wheel is carried on a shaft at the top of the water-box *C*. The lever *D*, raised and lowered by the right hand of the workman, passes the face of the grinding-wheel back and forth over the lip of the drill. The hand-wheel *E* adjusts the face of the stone to the lip of the drill; that is, it regulates the cut by setting up the stone closer to or farther from the part to be ground. To this hand-wheel is adapted an adjustable stop, which enables an adjustment to be made separately when grinding each lip, and yet permits them both to be gauged to the same length by means of this final stop. If the final grinding of both lips is made without

any adjustment of the stone, the same result is obtained without the use of this stop. The grinding-wheel is protected by a cover, except where the drill comes in contact with it. In this cover is a curved water-way, through which water is delivered by an endless-belt pump, and from which it is thrown on the face of the stone and on the end of the drill in a continuous stream. The ball-handle *F*, operated by the left hand of the workman, rotates the drill back and forth in front of the grinding-wheel in a way to insure the proper clearance.

The Sellers Tool Grinding and Shaping Machine, represented in Fig. 2, is intended for grinding and shaping all the faces of almost any kind of lathe, planer, slotter, and shaper tools. The main features of the machine are as follows: A grinding-wheel is mounted in a cast-iron frame forming a large tank, which receives the water used for flooding the tool in grinding. Slide-rests are provided, by which a vertical and two horizontal motions at right angles to each other can be imparted to the tool-holding chuck. The slide-rests and chuck are carried upon a vertical slide, which may be moved up and down by the long lever which is operated by the left hand of the attendant, the object of this movement being to move the tool in a vertical plane up and down past the grinding-surface of the stone, and thus produce a plane surface on the tool. In grinding curved surfaces no vertical movement is given to the chuck holding

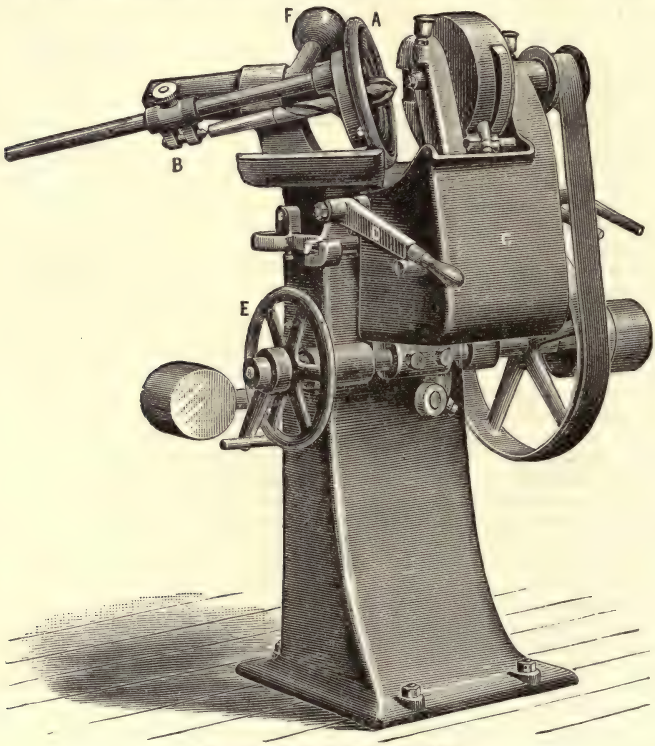


FIG. 1.—Drill-grinding machine.

the tool, but it is made to rotate, to produce the curve desired. If the curve of the tool is not a circular one, then a "former" plate is required. Means are provided by which any sample tool, whether ground by hand or otherwise, can be used as a templet for grinding the "former plate" to be afterward used for the reproduction of the shape of this sample tool. These formers simply consist of small cast-iron plates ¼ in. thick. The chuck which holds the tool can be rotated in two planes at right angles with each other, and the exact amount of rotation in either plane is indicated by graduated circles and verniers, so that any desired angle of tool or of clearance can be accurately obtained. For grinding the curved-face tools, the former plate is first selected and placed in the machine; then the tool to be ground is placed in the swinging-chuck with the base of the tool toward the left, and pushed forward against the end gauge until the index-finger of this gauge points to the number given in a table furnished by the makers, showing the vertical and horizontal angles which they have found best in practice, *plus* the amount required to be ground off the tool. The tool is clamped in the chuck and the chuck-swing, so that the entire curve of the tool will rub against the end gauge. The oscillation of the index-figure is noted, and the chuck adjusted by means of the handle on the left, until these oscillations are reduced to a minimum. The tool will then be in the best position for grinding.

For grinding lathe, boring, and chasing tools, planer-hook tools, and slotting-splining tools, supplementary chucks are used and set to the angles given for corresponding straight

tools. The periphery of the grinding-wheel is not at right angles to the flat surfaces of the wheel, but is formed so that in the section the grinding surfaces will form a V containing an angle of 90°. With this shape of stone a vertical surface perpendicular to the axis of the stone can be ground by moving horizontally the chuck with tool toward the center of the wheel; then, without disturbing the tool or making any change whatever, a vertical surface at right angles to the former surface can be ground by moving the tool horizontally in a direction parallel to the axis of the wheel.

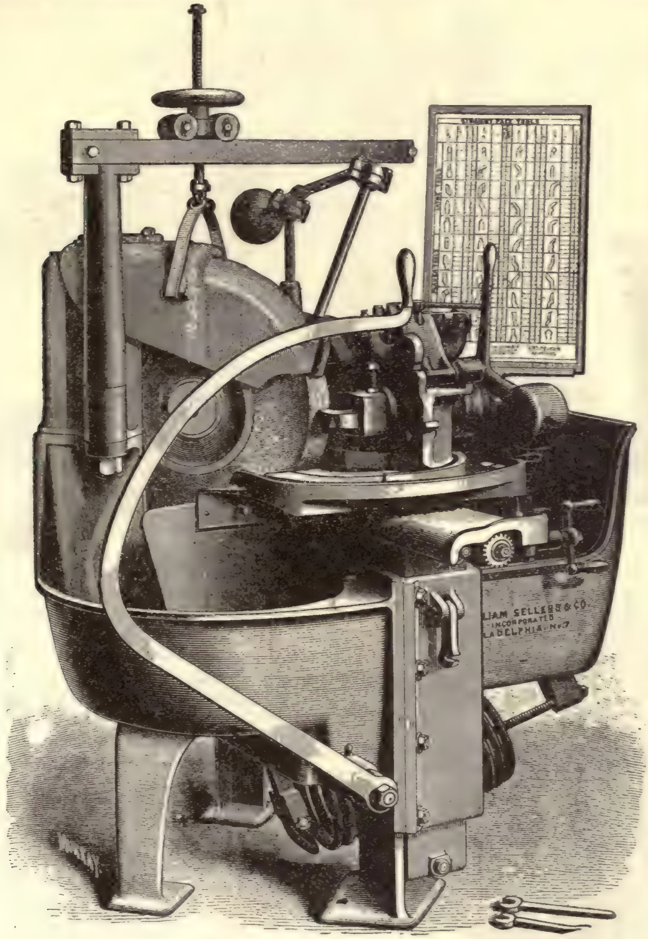


FIG. 2.—Tool-grinding machine.

Lapping-Machine.—This is a grinding device consisting of a lead or other soft metal surface, on which emery or oil is used. The machine shown in Fig. 3 is made by the Pratt & Whitney Co., for grinding thin, flat pieces that can not well be clamped for milling without retaining their winding irregularities. With this machine it is claimed that an unskilled workman can grind a true surface at much less expense than milling would cost. The diameter of lap is 18 in.; weight of machine, 1,100 lbs.; speed of lap, 1,500 revolutions per min.

Brown & Sharpe's Universal Grinding-Machine.—This machine, shown in Fig. 4, is suitable for both straight and taper, internal and external grinding, and is used in the manufacture of spindles and boxes, either hard or soft cutters, either straight or angular reamers, arbors, jewelers' rolls, and standard external and internal gauges. The sliding-table carries a swivel-table, which turns upon a center-pin. This provides for grinding tapers without throwing the head and foot stock spindles out of line. In order that the swivel-table may be set accurately, it is provided with an adjusting screw. A scale shows the taper both in degrees and in inches per foot. The table may be fed and reversed automatically or by hand. The cross-feed is operated by hand. The head-stock is attached to a base-plate bolted to the swivel-table, and turns upon a center-pin. Its circumference at the lower edge is graduated to degrees. The foot-stock spindle is adjusted by a lever, and there is a spring to accommodate the expansion of the work.

The machine will swing work between centers 12 in. diameter and 30 in. long. The swivel-table can be moved to either side of its central position to grind tapers from 0 to 2 in. per ft. For grinding work on the face-plate or chuck, the head-stock can be set at any angle within the whole circumference. Two tapers can be ground, either internal or external, without changing any of the settings. The work can be ground upon fixed centers, being driven by a pulley which revolves upon one of them, or the head-stock spindle can be revolved while the work is held in a chuck. Wheels are used from $\frac{1}{4}$ in. to 12 in. diameter.

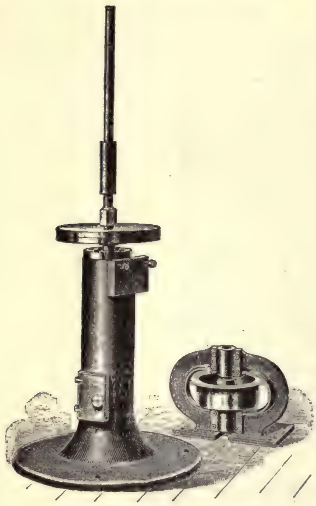


FIG. 3.—Lapping-machine.

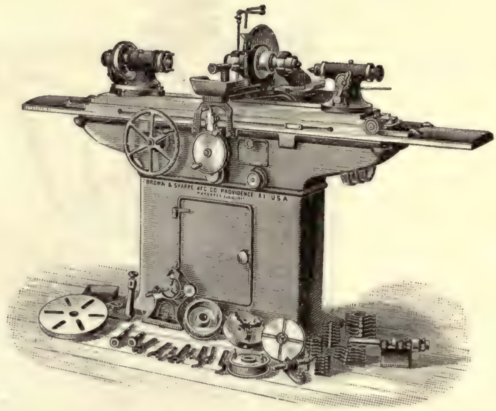


FIG. 4.—Universal grinding-machine.

Brown & Sharpe's Cutter and Reamer Grinder.—This machine, shown in Fig. 5, is extensively used for sharpening straight or taper, shell or shank reamers; and for grinding edge and bevel cutters of any angle; straddle and face mills, cotter and hollow mills, and straight or taper milling cutters, cut either straight or spiral, with holes or shanks. It can also be used for sharpening worm or thread tools. In operating the machine the work is moved on and off the wheel, there being no lateral movement of the wheel.

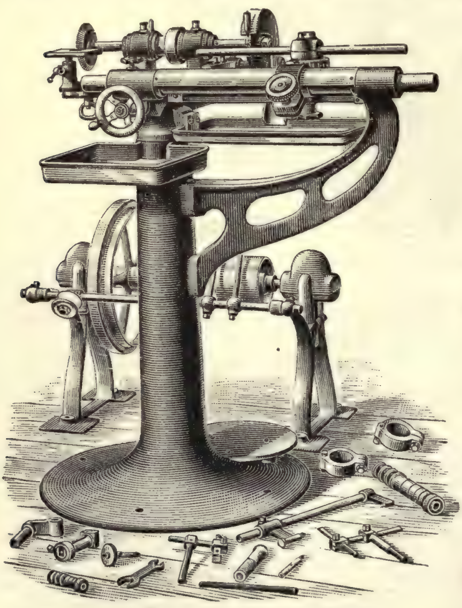


FIG. 5.—Cutter and reamer-grinder.

The Newman Emery Planer, made by the Tanite Co., is shown in Fig. 6. This machine is used especially for grinding dies, chilled castings, and steel, and also as a substitute for the ordinary planer. The principal dimensions are as follows: Floor-space, 29 × 36 in.; length of spindle, $42\frac{1}{2}$ in.; diameter of spindle in bearings, 2 in.; diameter of spindle between flanges, $1\frac{1}{2}$ in.; size of pulley on spindle, $5\frac{1}{2} \times 5\frac{1}{4}$ in.; throw of spindle, $9\frac{3}{4}$ in.; size of table, 36 × 10 in.; vertical movement of table, 17 in.; horizontal movement of table, 36 in. As a maximum this machine has taken a cut $\frac{1}{4}$ in. deep, and has taken a $\frac{1}{16}$-in. cut over a surface of 100 sq. in. in 6 min. and 9 sec. The ordinary cut is $\frac{1}{64}$ to $\frac{1}{32}$ in.

The Tanite Surface-Grinder is shown in one of several forms in Fig. 7. The surfacing-table is 24 × 8 in., and is adapted for wheels 14 × 3 in. With this machine many small jobs may be done which would otherwise go to the planer. The leading dimensions are: Height from floor to center of spindle, $37\frac{1}{2}$ in.; distance between wheels, $18\frac{1}{2}$ in.: floor-space, 22 × 26 in.; length of spindle, 29 in.; diameter of spindle in bearings, $1\frac{1}{4}$ in.; diameter of spindle between flanges, 1 in.

The Densmore Saw-Gummer is shown in Fig. 8. At A are the driving-pulleys, journaled between arms on a lower cross-piece, in which is also socketed the lower extremity f the elevating screw B. On the upper cross-head

is swiveled a yoke, to which is journaled a shaft C, carrying pulleys D. These transmit motion from the driving-pulleys A to the pulley E, on the emery-wheel shaft. The shaft C passes through a metallic block F, which fits loosely upon it, and which is ground off to a

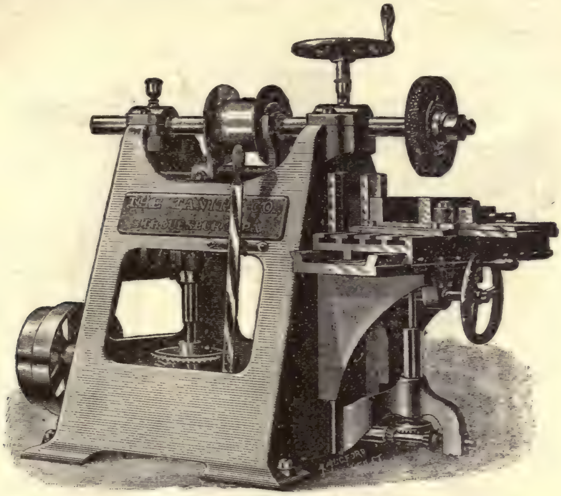


FIG. 6.—Emery planer.

point on its under side, to form a bearing for an adjusting screw. This block is also bored to receive the arm G, which supports the grinding-wheel. The arm G is movable in the block, and can be fastened in any desired position by the set screw H. I is a counterbalance

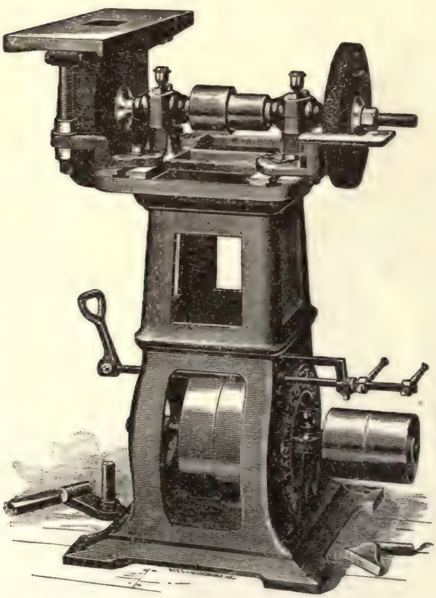


FIG. 7.—Surface-grinder.

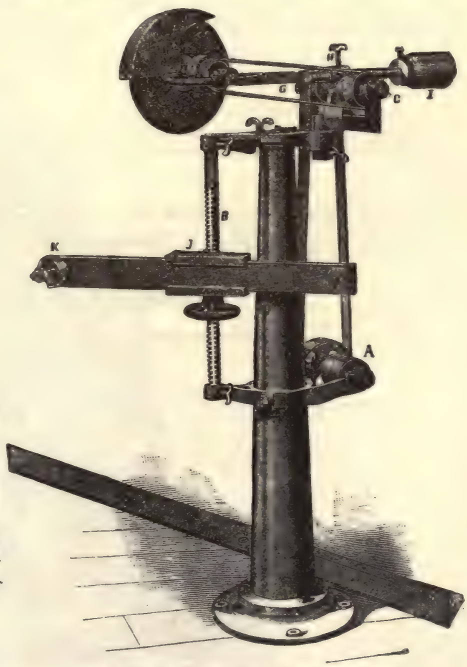


FIG. 8.—Densmore saw-gummer.

for the wheel. J is a stock, secured in place as desired, by a set screw not shown, and supported from below by the hand-wheel, by which it can be elevated and depressed. The stock has ways for a saw-bar, or a carriage with clamps for the blade. The saw-disk, in case a circular saw is to be gummed, is attached to the end K of the saw-bar, and the latter is properly adjusted and fastened to the stock, in such position as to bring the saw-teeth properly under the emery-wheel. The stock is then adjusted so as to bring it to a proper height by means

of the elevating screw, and the arm G is depressed in front until the wheel is in proper position. The wheel is previously adjusted to the proper angle of the tooth by partially rotating the arm in the block F, and securing it when the wheel is at suitable inclination. When the apparatus is to be used to gum a straight-edged saw, the blade is confined in a carriage, and the wheel is set in relation thereto, as already described. The saw is gradually carried forward by the carriage as each tooth is gummed.

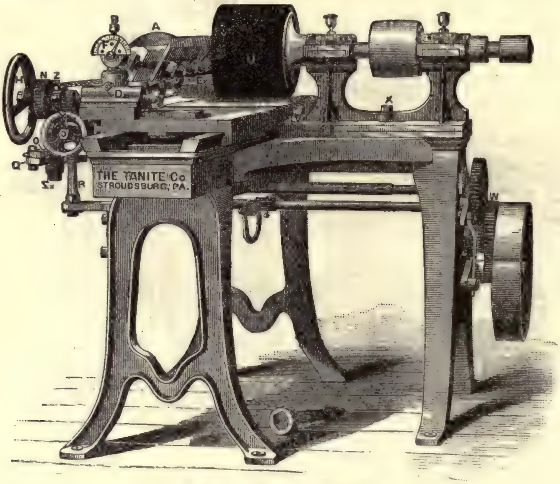


FIG. 9.—Knife-grinder.

The Tanite Automatic Planer Knife-Grinder is shown in Fig. 9. In this machine the knife is ground with a straight bevel with no change until the wheel is worn out, or it can be modified to grind a concave bevel, or square edges.

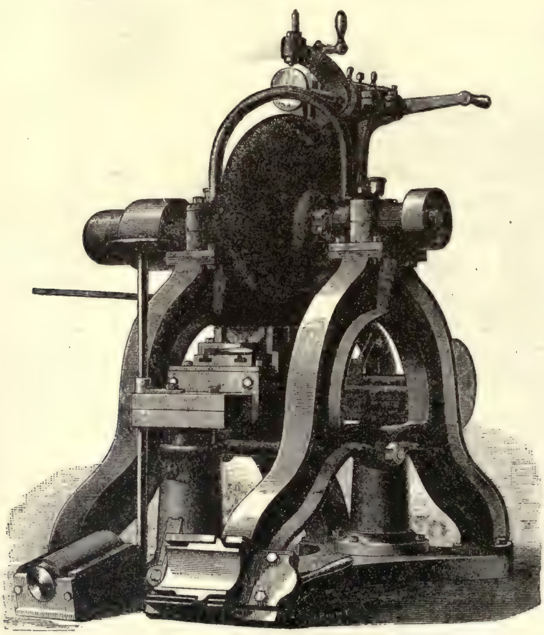


FIG. 10.—Car brass-grinder.

The Tanite Car Brass-Grinder is shown in Fig. 10. The brass is clamped between the jaws of the chuck by a cam-motion actuated by a handle. The chuck fits into planed guides, and thus travels square with the motion of the wheel. The table is moved horizontally by the crank and connecting-rod, and also rises and falls on planed ways, being pressed up by springs. The hand-wheel gives vertical adjustment to the bed by means of a chain beneath the base of the machine.

Groover: see Gaining-Machines.

Grubber: see Pulverizers and Harrows.

GUN, CARBONIC-ACID. An arm invented by M. Paul Giffard, in which liquefied carbonic acid is used to yield the propelling gas. Fig. 1 shows the gun, and Fig. 2 a longitu-

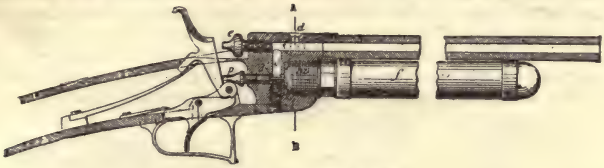


FIG. 1.—Giffard gun.

dinal section of the gas-chamber. The charge of liquefied gas, which replaces powder, is inclosed in a steel capsule *f* made fast to the barrel and screwed at *m* into the butt. This capsule terminates behind in a valve *g* pressed by a spring and the gas against a hard rubber seat *h*, and provided with a rod *j* that traverses at *j'* a tight packing *i* of soft leather. A rubber packing *l* secures, on another hand, the tightness of the threading *m*. As soon as the

FIG. 2.—Giffard gun—gas-chamber.

trigger is pressed the hammer strikes the extremity *p* of the rod *j*, and, through its impact, thrusts the valve *g* to a distance regulated by the stop *e*. There then escapes through *c* a certain quantity of liquefied gas, which expels the projectile that has previously been introduced into the barrel through a sort of cock *d*. As for the valve *g*, that is at once closed by the pressure of the liquid.

Gun: see Fire-Arms and Ordnance. **Gun-Lathe**: see Lathes, Metal-Working.

GUN, PNEUMATIC. The improved pneumatic ordnance designed by John Rapieff is adapted to the firing of projectiles containing high explosives. It consists, as shown in Figs. 1, 2, and 3, of a gun-barrel *A* that is provided from its breech to a point beyond the trunnions

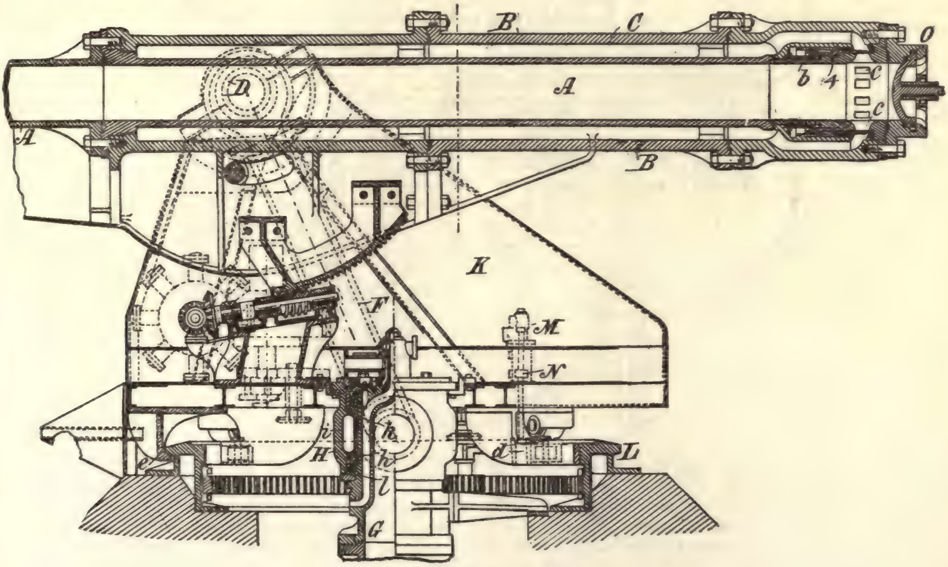


FIG. 1.—Rapieff pneumatic gun.

with a surrounding jacket *B*, connected by openings with the breech-end of the barrel, thus forming an annular space or reservoir *C* around the barrel for the passage of the fluid pressure to the breech. The barrel and jacket are secured together to form a rigid structure, thus the jacket carries the gun trunnions *D*, both hollow, and connected by balanced swing-joints *E* with fluid supply-pipes *F* that lead and branch from a fixed main central supply-pipe, the connection between the branches and the main pipe being also balanced, and a swing-joint *H*.

The jacket is formed preferably of three or more sections—the trunnion section, an intermediate section or sections, and the valve section—bolted together. The trunnion and intermediate sections are supported from the barrel by radial webs or studs, leaving ample space for the free passage of the fluid from the trunnions to the breech. The breech-end of the barrel contiguous to the main valve *4* is continued by an inner flanged bonnet *b*, having lantern-openings *c* for the admission of the fluid-pressure, and having radial and longitudinal passages to obtain efficient work of the valve. The valve section of the jacket is provided with ribs supporting an inner jacket, which, with the bonnet, forms a chamber for the main valve, from the back portion of which chamber through one of the ribs a passage is formed to the auxiliary valve. The forward part of the barrel, which is free of jacketing, is supported by a

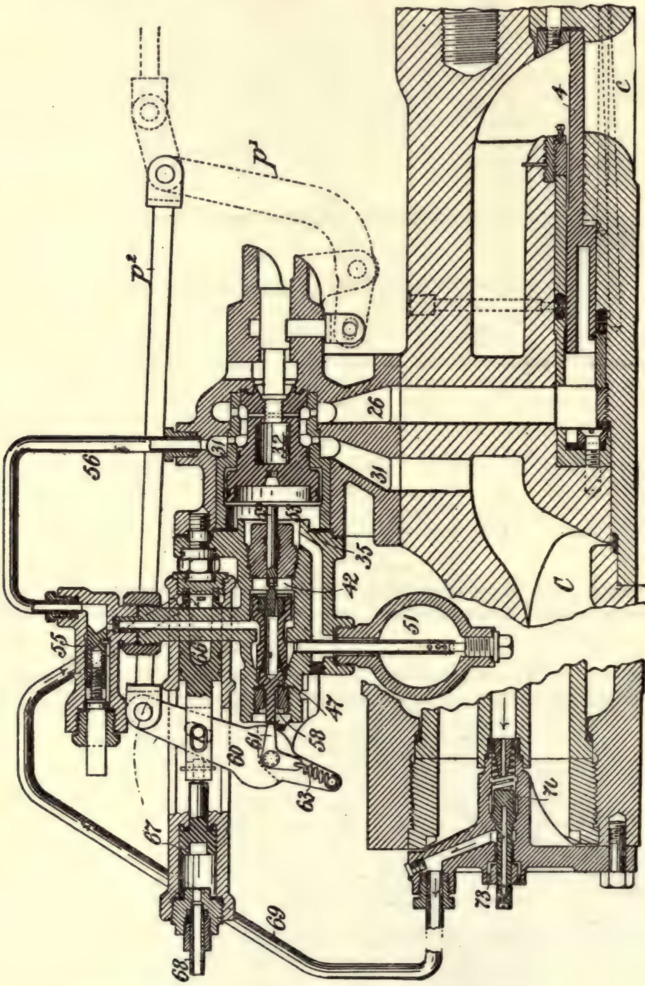


Fig. 2.—Rapieff pneumatic gun.

truss attached to the trunnion section of the jacket by bolts and keys. The barrel is supported on the truss by chairs which are adapted to transverse and vertical motion, so that the alignment of the barrel can be easily adjusted. The gun-carriage *K*, mounted to turn upon a suitable base *L*, is formed in the main of sheet, angle, I, and channeled irons, braced and also tied together; the vertical sides, each formed by a pair of legs, are housed by sheet-metal and secured at their upper ends to inner and outer castings, forming the trunnion-bearings. The carriage carries the motors—electric, pneumatic, hydraulic, etc.—for training the gun and for elevating.

The gun-carriage is provided with locking wedges *d*, by which the carriage, after each training movement, is securely held in its position upon the base. These wedges are operated to release the carriage just in advance of the movement of the motor to train the gun; and in the preferred arrangement, the fluid passing through passages in the head of the central supply-pipe *G*, before passing to the motor, will first flow to the cylinders *M* to operate the wedge-pistons *N*, and having raised them will then pass to the motor to operate it. The ar-

rangement is also such that as soon as the carriage stops the fluid acts to return the wedges, to secure the carriage. The wedges thus prevent any local motion of the carriage with respect to its base, so that during the firing the base and the foundation are brought together to resist recoil.

The carriage is formed with front and rear hooks *e* to engage with flanges on the base, to reduce all lateral and vertical motions during recoil. The carriage, besides the platform to

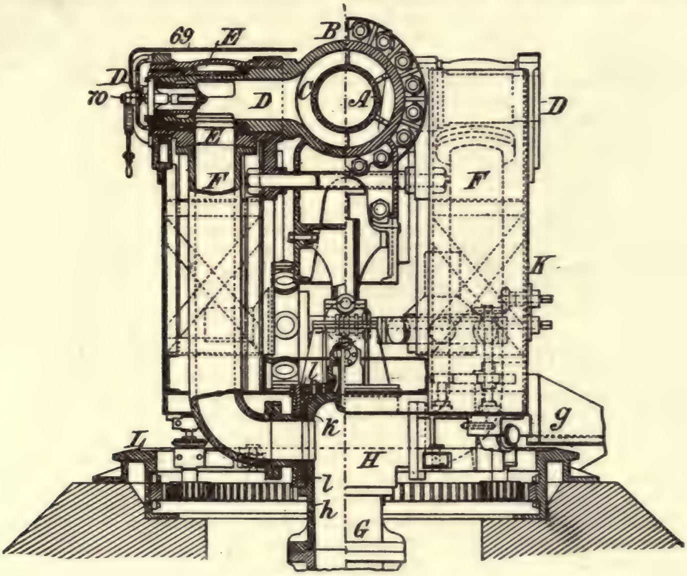


FIG. 3.—Rapieff pneumatic gun.

operate the firing, training, and elevating mechanism automatically, is also provided with means for training it by hand from a special platform *g*, and with eyes and hooks for tackle training. The balanced swing-joints of the trunnions, and the branch supply-pipes with the main pipe, are in the main similarly constructed. They each consist of an inner pipe *h* (Fig. 1), having radial passages, and an outer casing *i* having an annular passage, with which the radial passages communicate, so that both are constantly open, and the joint balanced by the pressure of the fluid, whatever the relation between the pipe and casing. The joint between the two is packed by suitable packing carried by a packing-carrying annulus *k* which surrounds the inner pipe, having openings corresponding to the radial passages in the pipe and supports both the packings *l*, arranged upon opposite sides of the joint, whereby, upon the removal of the annulus, the packings are simultaneously bodily removed therewith, and without the necessity of disturbing, removing, or dismantling any other parts. These packings are spaced and supplied with a liquid for sealing, and if need be lubricating, the joint. To prevent the leakage of the fluid through the metal of the casing, which, being of cast metal, may be more or less porous, there is interposed between the carrying annulus and the casing a ring or lining, formed preferably of bronze or copper; and in addition to the packings carried by the annulus, the latter, and also the ring or lining, is stepped and sealed against packings, held on corresponding steps on the pipe and casing.

In this joint, and in others belonging to the gun, the connected pieces are arranged, metal to metal, to insure perfect alignment, and the packing recess has its sides opposite to that of the fluid-pressure angularly disposed, so that the packing, whether solid, hollow, or cup-shaped, is crowded toward the joint by the fluid-pressure. The recess is formed with a restricted portion, so that the connected pieces will bite upon the packing to obtain an initial sealing, and this restricted portion is also large enough to receive any excess of the packing that may be forced into it on the complete assembling of the pieces. This arrangement also permits the use of many face-to-face joints properly packed. The valves of the gun consist of a main firing-valve *4*, controlling the openings *c* between the jacket-reservoir and the gun-breech behind the projectile; an auxiliary valve *32* (Fig. 2), arranged in a casing secured to the valve section of the jacket, for opening and timing the opening of the main valve, said auxiliary valve also embracing a tappet fly-over valve *47*, a tripping-lever or detent *60*, and a supplemental valve *66* for moving the lever or detent; and a pilot-valve *70*, located in a casing in the left-hand trunnion, with a hand-lever for operating it, the said valve controlling the admission of fluid through the pipe *69* to automatically operate the auxiliary valve. The main valve is an annular one, normally seated to close the breech communication, and held seated by the fluid-pressure on its back end; the auxiliary valve in its normal closed position connecting the fluid-pressure passage for this purpose, is also held in this position by the fluid-pressure. The auxiliary valve is a piston-valve, having differential areas controlling

passages *26*, *31*, for the fluid to hold the main valve closed, and when moved closes one of said passages (*31*) on the pressure side, and opens the other (*26*) to the atmosphere, so that the pressure may exhaust from behind the main valve and allow the fluid-pressure on the other side of the main valve, acting upon a shoulder for that purpose, to operate to move said valve open. The tappet fly-over valve is normally held closed, and so allows the fluid-pressure to act upon the larger area of the auxiliary valve as well as upon the area of itself, has its initial motion imparted by the movement of the tripping-lever or detent by hand, or through the action of the supplemental valve by the admission of pressure from the trunnion on the opening of the pilot-valve. The movement of the tappet-valve shuts off the fluid-pressure from the larger area (back chamber *53*) of the auxiliary valve and from the like area (back chamber *42*) of itself, then opens connection with its back chamber to the atmosphere through opening *58*. The back chamber of the tappet-valve being exhausted, the fluid-pressure acts upon the differential shoulder of the valve and automatically moves it the remaining part of its stroke till it seats on buffer in the back chamber, thus avoiding all personal equation in firing. Its tappet *59* participates in this motion, having been farther projected into the back chamber *53* of the auxiliary valve. In this position of the tappet-valve the back of auxiliary valve is open to the atmosphere through bulb *51*, and tappet-valve to opening *58*. This exhausts said back chamber, and the auxiliary valve moves open by the fluid-pressure upon its first differential shoulder, the second differential shoulder being idle. The auxiliary valve moves under this pressure until the pressure is allowed to act upon the second differential shoulder, when the valve is forcibly seated to its buffer *35* at end of the back chamber. In the latter part of its stroke it meets the tappet *59* of the tappet-valve and forces the tappet-valve almost to its normal position, then the pressure is admitted in back chamber of the tappet-valve, which completes the movement. The fluid-pressure is then admitted to back chamber of the auxiliary valve and moves this valve back to its normal position.

In the passage composed partially by the pipe *56* between the fluid-pressure supply *31* and the back chamber of the auxiliary valve, there is placed a regulating cock *55* and the bulb *51*, by means of which the duration of opening of the auxiliary and main valve is regulated—the regulating cock is adapted to vary the size of the admitting orifice for the pressure, and the bulb its capacity. The passage from auxiliary valve is extended to near the bottom of the bulb to insure the effectiveness of the operation of the bulb.

The supplemental valve operating the tripping-lever is composed of two piston-valves *66*, *67*, of different areas, joined loosely together, the stem of one of the valves being connected to the tripping-lever. The smaller valve is normally seated by pressure from the reservoir through pipe *68*, while the pressure to the larger valve is admitted by pipe *69* during the moment of firing by the opening of the pilot-valve. The tripping-lever or detent is provided with a trigger *61*, held in position by a spring *63*, arranged in such manner that when the movement of the lever is complete it removes the trigger from the end of the tappet-valve, so that the latter may be free to return.

All the valves are constructed so that the leakage of the pressure is prevented by seating them endwise against seats and buffers in their respective chambers; and their seating faces may be concaved or grooved to insure more complete seating and longer life of the seat. The pilot-valve *70*, controlling the admission of fluid from the jacket-reservoir to the supplemental valve, is held closed by the fluid-pressure, a spring being provided to return the valve closed should the pressure be absent. The stem of this valve is perforated longitudinally and with radial openings, so that, should the pressure leak past its valve when seated, it will pass to the atmosphere without danger of passing to the supplemental valve, the exhaust from the chamber of the latter being regulated by screws *73* adjacent to the stem of the pilot-valve.

The gun-breech is opened for the insertion of the projectile and tightly closed by a packed breech-gate *O*, pivoted to the breech-casting and adapted to rotate and swing open and shut. The breech-gate has an interrupted flange, so that it and its gate-lever *o* need be moved but a fraction of the circle to release the gate. With the gate is connected a locking-gear *p*, which, as the lever is first moved to release the gate, the latter moves the locking-gear through connecting-rods p^2 and lever p^1 into position to positively lock the auxiliary and supplemental valves and tripping-lever *60* against accidental movement from their normally closed position, as, for instance, by inadvertently moving the pilot-valve hand-lever. The packing-gear is provided with a spring or similar device, so that upon the opening of the gate it is automatically locked against accidental movement until the gate is closed. The gun-breech is also provided with a vent-opening just in rear of the projectile which is normally open to the atmosphere, so that, should the fluid-pressure leak past the main valve into the barrel, the projectile will be in no danger of being prematurely fired therefrom. This vent may be controlled by a spring-pressed valve held open against any pressure caused by a leakage into the barrel, but which will automatically close upon the sudden admission of the pressure into the barrel. It may, however, be controlled positively by a valve moving positively in unison with the auxiliary valve or any other movable part of the system, as through rods from p^2 with the tripping-lever *60*, so that upon the early movement thereof the vent-valve will have closed the vent, and thus prevent the leakage of the fluid-pressure when the projectile is to be fired.

The loading-carriage consists of a wheeled truck running on a circular way having the training axis of the gun-carriage as its center. The wheeled carriage supports a pair of rails, inclined to an angle of loading. On these rails is supported the projectile-trough, that can be moved back and forth by a pinion and rack or a winch, operated by a hand-lever, to deliver the projectile into the breech of the gun. The trough is held in position by a spring-pressed detent, carried by the truck, acting against a stop on the trough. The trough also carries a

loading-ram, moved by rope and pulleys connected with a hand-operated winch supported by the truck, to force the projectile into the gun-barrel. The truck is also adapted to transfer projectiles from the magazine to the gun. (See also TORPEDOES.)

Hammer, Pile-Driving: see Pile-Driving.

HAMMERS, POWER. No important improvement has been made in steam-hammers during the last ten years, but a notable event in the history of steam-hammers is the erection and completion in 1891 of the largest hammer in the world, at the Bethlehem (Pa.) Steel-Works. A description of this enormous hammer is given below:

The hammer stands in the center of a very large building, and over a year has been spent in its construction. A pit 58 ft. × 62 ft. was dug for the foundation, and on walls 30 ft. high the anvil stands. To give the foundation a certain elasticity, a layer of twenty steel slabs on top of Ohio white-oak timbers was made, and the surface was rendered perfectly smooth. The anvil was built by depositing on top of the steel slabs and their timbers twenty-two blocks of solid cast iron. The average weight of these blocks is 70 tons, and the entire weight of the mass of iron and steel forming the anvil and foundation is nearly 1,800 tons. The anvil foundation and the hammer foundation are entirely separate and independent of each other. The hammer itself is a majestic looking structure, rising to a height of 90 ft. The housings, composing the first section, from a large arch. These housings are each composed of a single 120-ton casting. The width of the hammer is 42 ft. The housings, whose bases are 10 ft. by 8 ft., are firmly clamped into the foundation-walls at each side, and are fastened to washers lying beneath the walls at a depth of 33 ft.

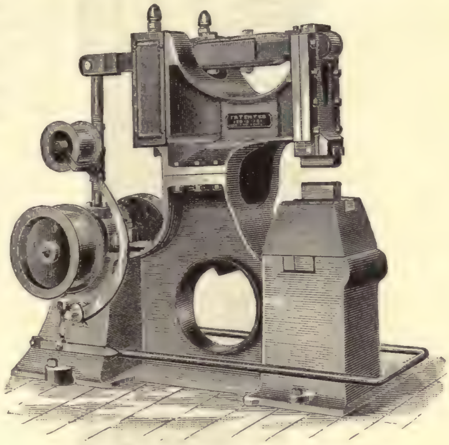


FIG. 1.—The Jenkins cushioned hammer.

Around the entire periphery of the hammer, to the height of the first section, 15 ft., is a platform of levers controlling the working of the machine. Above is another arch of housings, which weigh 80 tons apiece. This arch is capped by a steam-chest, a casting of 65 tons. Here, at the height of some 70 ft., is another platform. On the top of this steam-chest, and in the center of this platform, is superadded the huge cylinder, 24 ft. high, with an internal diameter of 76 in. In the zenith of the arch is the large tup or ram of the hammer, an enormous piece of metal about 19½ ft. long, 10 ft. wide, and 4 ft. thick, the weight of which is almost 100 tons. Connected to this is the piston-rod, of steel, 40 ft. long and 16 in. in diameter. At the bottom of the tup and keyed to it is the die-hammer. This is a large, square block of iron, faced with steel, and is the piece which will strike the metal that is being forged. The piston-rod has a stroke of 16½ ft., and the weight of tup, piston-rod, and piston aggregates 125 tons.

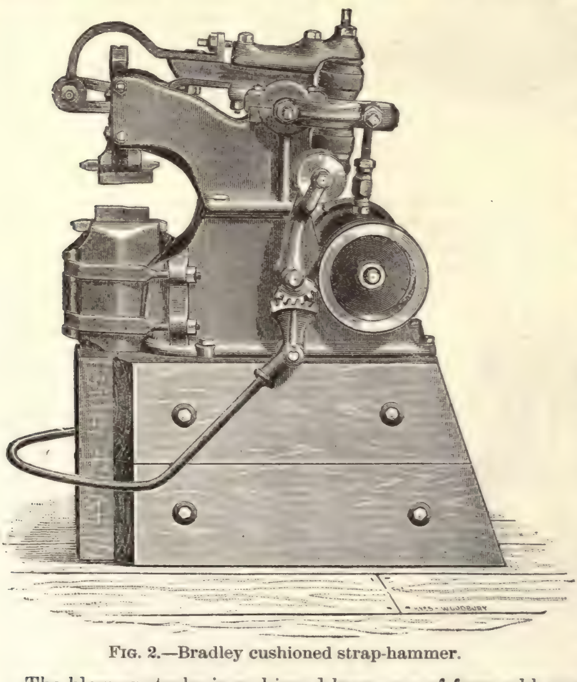


FIG. 2.—Bradley cushioned strap-hammer.

Jenkins' Upright Cushioned Helve-Hammer.—Fig. 1 shows a power-hammer made by Jenkins & Lingle, of Bellefonte, Pa. The blow or stroke is cushioned by means of four rubber cushions, two of which are placed above and two below the fulcrum bearing the helve. This fulcrum is made in the form of a cross-head, to which the head is pivoted; the cross-head being free to move up and down as the strain comes on the helve. The makers claim that a cushion placed directly at the ful-

crum is more effective than when placed at a distance from it, as every inch farther from the fulcrum requires proportionately more movement of the cushions to produce the same result on the ram. The end of the helve joining the ram is wood, and simply enters into an opening provided in the ram.

The Bradley Upright Cushioned Strap-Hammer, shown in Fig. 2, has a helve of steel, in an arched form, with the head or ram carrying the die sustained and operated by an endless leather strap, suspended between spool-shaped bearings, and extending lengthwise of the helve. This device allows of the utmost opening between the dies, either at rest or in action, and its elasticity and freedom of motion increases

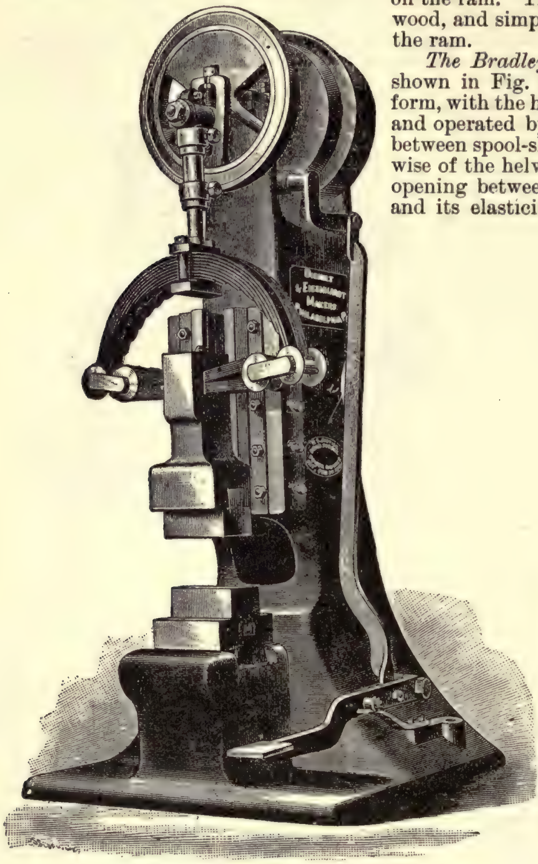


Fig. 3.—Dead-stroke power-hammer.

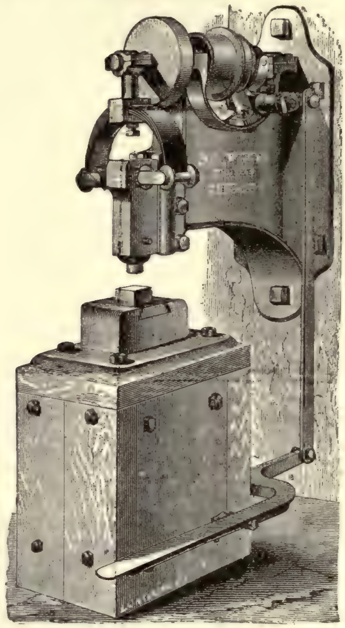


Fig. 4.—Dead-stroke power-hammer.

the throw of the ram, while at the same time the stroke of the eccentric is shortened. The hammer is operated by an eccentric at the rear, connected by a pitman to the saddle or oscillator which carries the helve, and by this helve motion is imparted to the head or ram. In this way the blow is made to imitate the action of a hand-hammer.

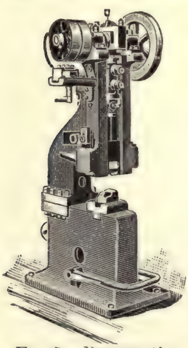


Fig. 5.—Pneumatic hammer.

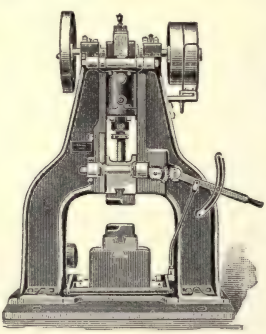


Fig. 6.—Pneumatic hammer.

Dead-Stroke Power-Hammer.—Fig. 3 shows a dead-stroke power-hammer, made by Dienelt & Eisenhardt, of Philadelphia. The ram, or striking part of the hammer, is suspended on an elastic or flexible belt (generally of leather), attached to the extreme points of a semicircular steel spring. The upper part of the steel spring is connected by a rod with a crank-pin, which, being set in motion by belting, gives the reciprocating movement necessary to raise or lower the ram, in its guides, with a speed and force entirely regulated by the friction-pulley. One peculiarity of this hammer is that, although none of the force with which the ram descends is lost, the rebound is taken up by the spring and belt on which it is suspended, before reaching the working parts above it. In this way the shaft-bearings, crank-pins, and set-screws are preserved from breakage. It may be readily adjusted to work exclusively on thick metals, yet for ordinary work a 50-lb. hammer, for example, will strike good alternate blows on a 3-in. or ⅜-in. bar without any change in the adjustment. Fig. 4 shows a hammer of the same kind set in a wall-bracket. This hammer has

a shorter stroke than the standard hammer; hence it is not so powerful in its blow, although it moves very rapidly if desired.

Pneumatic Hammer.—The Hackney pneumatic hammer is shown in Figs. 5, 6, and 7. Hammers of this kind strike their blows through power derived from air which has been compressed in a cylinder by a piston. The air acts when imparting its force precisely like a powerful compressed spring suddenly released, and, in fact, it is such a spring; hence such hammers are sometimes called air-spring hammers. Fig. 5 is the single standard hammer designed for comparatively light forging. Fig. 6 is a double standard hammer, and is suitable for heavy work. The same principles of working are, however, embodied in each, as is shown in the diagram cut (Fig. 7). The crank-yoke is attached directly to the air-cylinder below, which is thus given a vertical reciprocating motion in the slides. Within this cylinder is a piston attached to the hammer-head, the air, more or less of which is confined above and below the piston, serving to transmit motion to it and to cushion it at the end of each stroke. The admission and confinement of air in the cylinder are controlled by valves, by which air may not only be confined above the piston but also below it, thus holding the piston between two air-springs, each of which opposes the action of the other; and this opposition is regulated at the will of the operator, so that it may be increased till the force of the blow is reduced to nothing, or diminished so that the full force of the hammer is realized; the intensity of the blow depending upon the position of the valves.

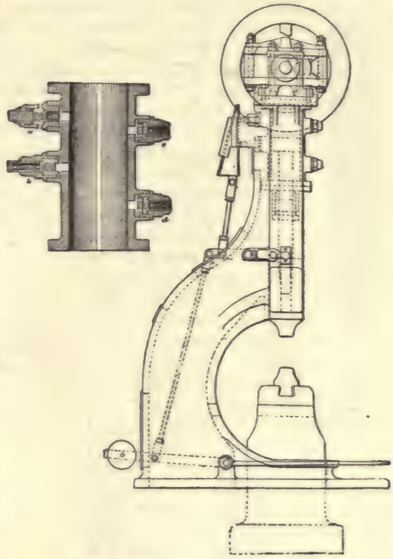


FIG. 7.—Pneumatic hammer.

Harness, Fire: see Fire Appliances.

Harpoon: see Hay Carriers and Rickers.

Harrow: see Pulverizers and Harrows.

HARVESTER, COTTON. The difficulties in the way of a successful cotton-harvester arise from the peculiar nature of the crop. A field of cotton is not harvested once for all, as is a field of grain, chiefly because the cotton on the plant does not ripen all at once. It therefore may happen that on the same plant there may be lint, ready for picking, immature bolls, and even the flower or bloom. In the eastern States of the South it is common to gather three crops; the first early in the autumn, the last usually in December. It is, therefore, essential beyond all other considerations, that a cotton-harvesting machine should be so constructed that it will remove only the lint from the plants, and nothing else. This implies two things: first, that the plant itself, with its bolls and blooms, shall be left unimpaired by the action of the machine; and, second, that the gathered cotton shall be free from leaves, sticks, or other trash. The early attempts at inventing cotton-machines, and most of the modern efforts, have failed because of non-fulfillment of one or the other of these conditions. The trouble with most of them has been that they would not only gather the cotton, but a good deal of the plant at the same time; and even if this were not detrimental to the harvesting of subsequent crops from the same plant, it would be fatally uneconomical, for the reason that the cost of getting the trash out of the cotton which is gathered far overbalances the gain incident to the use of machine-picking. It has become almost a maxim in the South that "cotton can only be picked by brains." A great many machines have been devised which have failed simply because they could not get at the cotton at all. Others have been provided with claws and fingers, and all kinds of catching contrivances, which would entangle the cotton, but which, as already stated, would make no discrimination between lint and trash. The makers of the earliest machines discovered that large claws or fingers would generally pick the boll with the lint, and then the sizes of the fingers or claws were diminished, until finally it was attempted to gather cotton with ordinary card clothing. After this came attempts to pump the cotton from the plant; and then followed efforts to make it adhere to an electrically excited belt. None of these attempts has been even measurably successful. Most of the inventors have erred in the belief that what is wanted in a cotton-harvester is a machine which will imitate the operations of a man in picking cotton. This is a mistake. What is wanted is a contrivance which will not only take cotton off the plants, but which will take nothing but cotton; or, in other words, which will discriminate. The most promising cotton-harvester which thus far has been produced is that invented by Mr. Charles T. Mason, Jr., of South Carolina; and, so far as is known, Mr. Mason appears to have been the first person to have recognized the correct principles of cotton-harvesting as above briefly outlined. He invented, first, what he calls a "stem," which is a device which will take cotton and nothing but cotton from the plants. He has also invented several forms of machines which operate that stem to bring it into contact with the cotton out of the successive plants of a row. The principle of Mr. Mason's stem will be readily under-

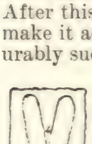


FIG. 1. Stem tooth.

stood from Fig. 1, which represents a piece of thin sheet-metal, *A*, in which has been cut a V-shaped slot, *B*. This slot is shown in the figure very much enlarged over actual size, its length, in practice, being about a third of an inch. In the metal plate is punched a series of these V-shaped slots arranged in rows, after which the plate is corrugated and bent to form a cylinder or completed stem, as shown in Fig. 2. It will be noticed that in the slot *B* there is formed a sharp tooth *L*. This tooth is so placed that it does not project above the surface of the cylinder or stem, or, in other words, it is guarded by the adjacent metal. It will also be observed that there is considerable open space in the slot in front of the tooth *L*. Now, when the stem, Fig. 2, is brought up to a mass of loose cotton lint, the latter, by its own elasticity, will enter the space in front of the tooth *L* and will become engaged. When the cylinder or stem is turned with the points of its teeth foremost, nothing which is not as elastic as cotton will enter the space in front of the tooth, but the surface of the stem will slide or rotate in contact with it. Therefore it is impossible to make the stem gather leaves, or stalks, or bolls, or any other hard substance. So accurately will this stem discriminate, that it may be taken in the closed hand and rotated point foremost, and yet will not scratch the skin; but the instant that it touches the elastic cotton, engagement follows. It will be obvious that, in order to use such a slot as this, a mechanism must be provided which will rotate the stems points foremost, gather the cotton, and then rotate them in the opposite direction to throw the cotton from the teeth. The mechanism must also carry the stems bodily into and out of the plants, while the machine itself is progressing forward along the row. It will be clear that there are many ways in which this can be done. Thus, the stems, mounted on suitable frames, may be dipped into the plants from above, which perhaps is objectionable on account of the necessary height to be given to the machine, or they may be introduced laterally. One form of the machine which Mr. Mason has devised, and which has been successfully used, is illustrated in Figs. 3 and 4, Fig. 3 being a vertical section and Fig. 4 a plan. The body consists of a box-shaped frame mounted on two wheels. The frame is divided into two parts or sections, with a passage-way in the center, so that the machine, so to speak, straddles the cotton-row. In each section of the machine there is a vertical shaft, and on this shaft the cotton-stems are arranged radially and in tiers one above the other. Motion is communicated to the shaft by gearing from the wheels, so that the shaft rotates, and in so doing carries the stems into the plants, and then into the compartments of the machine. In connection with the stems a reversing gear is arranged, so that the stems are made to turn on their own axes, points forward, while in the plants, and in a reverse direction when they enter the boxes. The stems, therefore, gather the cotton, carry it into the boxes, reverse, and thereby clear themselves of the cotton; and the latter then falls upon a horizontal belt, which conveys it to the rear, where it engages with elevator-belts, and these in turn carry it upward and deliver it into the bags hung on the rear of the machine. The machine is drawn by a horse or mule, and as it passes over the rows of plants the stems are carried backward in each rev-

FIG. 2. Stem.

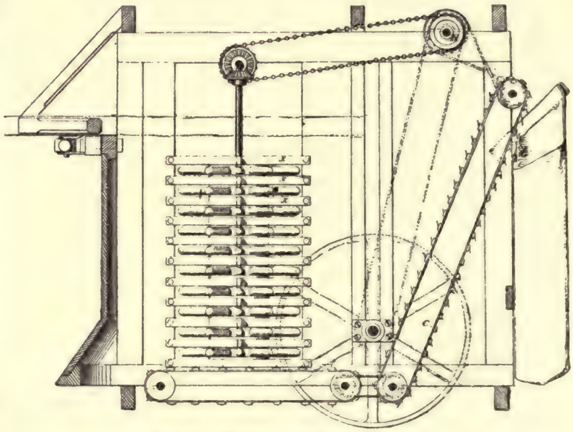


FIG. 3.—Mason cotton-harvester.

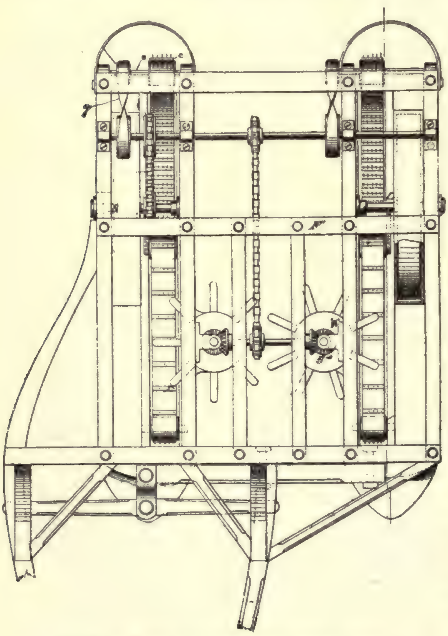


FIG. 4.—Mason cotton-harvester—plan.

olution at the same rate of speed as that at which the machine moves forward. Therefore, the stems are practically stationary in the plants, and all dragging is prevented. Actual experiment has proved that the capacity of this machine is from 3,000 to 3,500 lbs. per day. A committee of the National Cotton Planters' Association has reported that, under conditions of actual test, "the machine gathered a fairly clean cotton at the rate of 240 lbs. of seed-cotton per hour from plants that would not yield more than 1 bale of line cotton to every 3 acres"; and that the committee could "discover no damage done in the operation of the machine to the plant in any way, either to the unopened bolls or the leaves on the stalk." The machine described is manufactured by the Mason Cotton Harvester Company, of Charleston, S. C., and further details concerning it will be found in the following letters-patent granted to Mr. Charles T. Mason, Jr., namely, 286,032, Oct., 1883; 293,484, 293,485, Feb. 12, 1884; 311,344, Jan. 27, 1885; 312,647, Feb. 24, 1885; 331,514, Dec. 1, 1885; 337,007. March 2, 1886; 345,246, July 6, 1886; and 345,312, July 13, 1886.

HARVESTING-MACHINES, GRAIN. The construction of binding-harvesters has been changed to some extent as regards the harvester part, and radically in the binder part, since the year 1880, and the use of this compound implement has been largely increased by the very preferable employment of twines instead of wire to bind the sheaves of grain. Manila twine was early chosen by Holmes, Gorham, Appleby, and other early workers in the invention of the grain-binder, and manila hemp still holds favor for this purpose. Sisal hemp comes very near it as a suitable fiber. Without a proper twine the machine would have been far from the remarkable success it has become. Grain-binders now consume in the United States more than 60,000 tons of twine annually. There is no consequential objection to the twine; but the wire, from which small fragments broke away in the operation of thrashing by

FIG. 1.

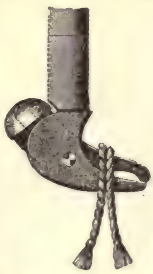


FIG. 2.

FIG. 3.

FIG. 4.

FIG. 6.

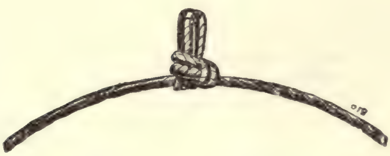


FIG. 7.

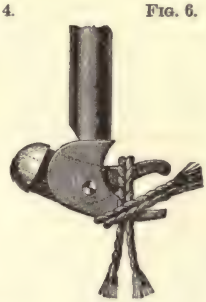


FIG. 5.

FIGS. 1-7.—Operation of Appleby knotter.

machinery, injured the expensive bolting-cloths of the flouring-mills to an appreciable extent, owing to the sharp cutting edges of the fragments becoming flattened by the mill machinery. It was claimed, also, that farm animals were sometimes choked or injured internally by bits of the wire, as these were found in the stomach and bowels after death. A grave prejudice was aroused against grain-binders, employing wire as the binding material, which the substitution of twine has quite allayed.

The introduction of the binding-harvester has been a tremendous stimulus to grain-growing not only in this, its native country, but throughout South America, Europe, Australasia, and parts of Africa. Some 3 ft. of twine will bind a convenient sheaf. It must be strong enough to bear about 70 lbs. tensile strain when made with a loose enough twist to avoid kinking, and must be spun free from swells and bunches unfit to pass through the mechanical knotter. The finer it can be spun, without sacrifice of necessary tensile strength, the more economical its use. In practice, it runs from about 400 to 600 ft. per lb., making it cost per acre, at current prices, from 28 down to about 18 cts. Other fibers besides those named are used to a moderate extent, also mixtures of the above with jute, ramie, and even American hemp. The Lowry twine is the latest improvement in grain-binding material—an improvement in the direction of economy. It is made of the tough slough-grass which grows abundantly on low-lying wet land throughout the United States in the great prairie basins, and is

deemed useless for any other purpose. It is twisted or spun, without preliminary preparation other than combing it straight, into a uniform, strong twine, by special machinery devised by George A. Lowry, of Iowa, which also at the same time wraps it with light cotton thread, at the instant before spooling, in a long, open spiral turned opposite to the direction of the twist given the twine in spinning. The thread-wrapping serves to hold the grass-twine twist firm, and also prevents protrusion of short ends that would possibly interfere with the work of a mechanical knotter. By enlarging and otherwise slightly modifying the lines of the knotting mechanism of grain-binders, this grass-twine and the ordinary hempen twines can be used interchangeably on the same machine—an obvious practical convenience. At present prices, the cost of it per acre of grain is considerably less than of the ordinary twines; and the ease of manufacture is also in its favor. At first, reduction in the cost of harvesting was the only consideration in introducing the mechanical binding, but it has proved to be scarcely the most important. So precarious is the state of grain crops when just fit for the sickle that either premature or dilatory harvesting forfeits large value. However, with the binder the crop is quickly taken off at the time deemed best. In the United States, the birthplace of the binder, the yearly yield of wheat, oats, rye, and barley has been enormously augmented since the advent of the use of the twine. Present crops of over 1,300,000,000 bushels of small grains in a year could not have been approached without it. The quality of crop has also visibly improved. The binding-harvester has therefore become the most important among the farmer's machines, though the rapid improvements of ten years have not yet had time enough to ripen all its possibilities. Not taking up the improvements from their crudity from the beginning of the decade step by step, we merely instance some advanced examples in common use at the end of the decade, which enable the farmer or his boy to sit the machine, drive unaided round and round his fields, and reap, bind, and deliver the grain-sheaves in groups of a sufficient number to form a stook, at the rate of from 1 to $1\frac{1}{2}$ acres an hour, according to capacity of team. It is used with horses, oxen, or, as in the broad California valleys, with the same steam-engine which has previously plowed, harrowed, and seeded the ground for it, and which will also thrash, clean, and bag the grain for market. The principles of the Marsh harvester, really designed to carry men to do the binding, has generally been relied on as the foundation for the machine; but there is now a breaking away from these limitations, to reduce weight, draft, and cost, by special construction, treating the reaping, gaveling, and sheafing as one continuous operation.

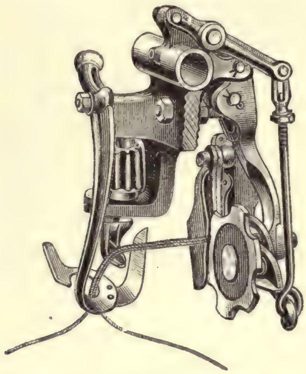


Fig. 8.—Knotter complete.

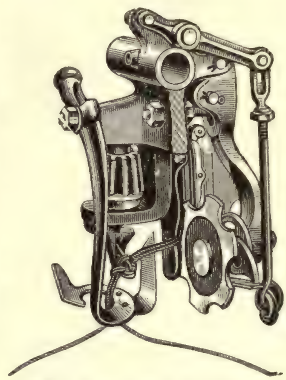


Fig. 9.—Knotter complete.

The Knotter.—The germ of the binding-harvester upon which all other parts are a growth, is the knotter, one type of which is seen performing its successive movement in tying the knot, in Figs. 1 to 6 inclusive. The completed knot, with a segment of the band, is seen in Fig. 7. The beveled pinion, seen in Figs. 8 and 9, which represents the complete appliance in two positions, rotates the knotter one revolution, and the loop thus formed in the doubled twine is then quickly stripped off from the knotter by mechanical means, leaving a bow still pinched in the knotter, and which has been passed securely through the tightly drawn loops. This bow of the knot is finally pulled from the grip of the knotter by

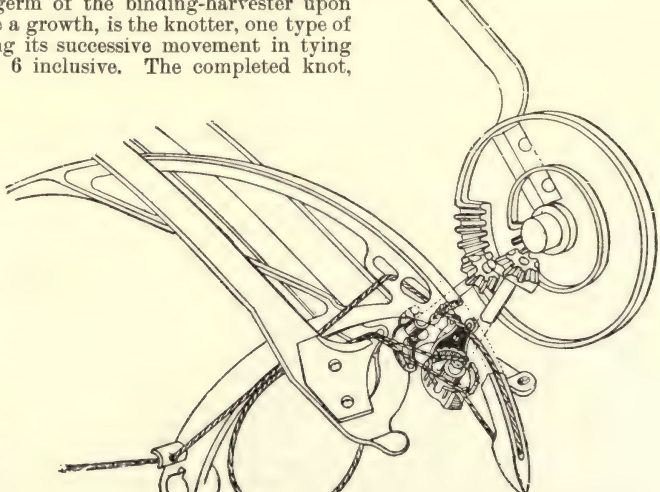


Fig. 10.—Twine-looper and knotter.

the strain of the bound sheaf as the latter is expelled from the binder-table by suitable discharging-prongs. At the instant of tying, the twine has been severed by a small blade between the knotter and a retaining device to hold the end of the twine which communicates with the source of supply carried in a box on the machine. The simplified diagram from the McCormick Co. (Fig. 10) will serve to show the usual plan of leading the twine necessary for a band up around the gavel to be bound, and presenting it upon the knotter and to the action of the retainer beyond, so that the latter may in due time, when releasing the end last held, seize the new end at the instant of severance, holding it upon the knotter parallel with the held end already there, while the knotter, with a rapid whirl, forms the next knot.

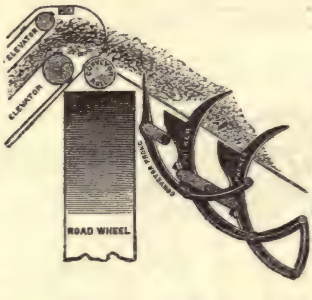


Fig. 11.—Binder-table.

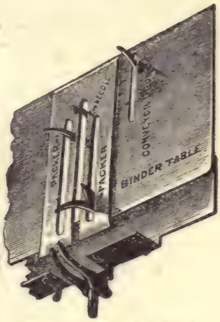


Fig. 12.—Binder-table.

The bowl-like knob seen in Fig. 1 at the heel of the jaw of the knotter serves to open and close the jaw for the reception and release of the two branches of the twine which are to form a knot of the free ends, and derives motion from a stationary cam-track, which it encounters during its rotation with the knotter. In this class of binder the grain delivered from the reaper-apron is propelled by a pair of alternating double-fluked packers protruding upward through the slotted table (Figs. 11, 12). The tip of the twine-needle is seen at the top of the middle slot (Fig. 12). When a sufficient bulk of grain has been packed against the upright double compressor-post, seen at bottom of Fig. 12, to overcome the adjusted resistance of the post, the latter automatically trips the shifter for starting the needle-arm shaft and knotting mechanism, producing the following series of movements: The needle rises and completes the encircling of the gavel with twine; the knot is tied; both branches of the twine are severed just beyond the knot; a new end of twine is retained; a pair of discharging-arms applied behind the sheaf ejects it from the table; the drop-boards seen on either side of the double compressor-post (Fig. 12) are lowered on their hinges to make way for the outpassing sheaf; the drop-boards are returned; the needle is lowered to its position of rest; the trip is automatically relocked; and the packing of grain for another sheaf is resumed.

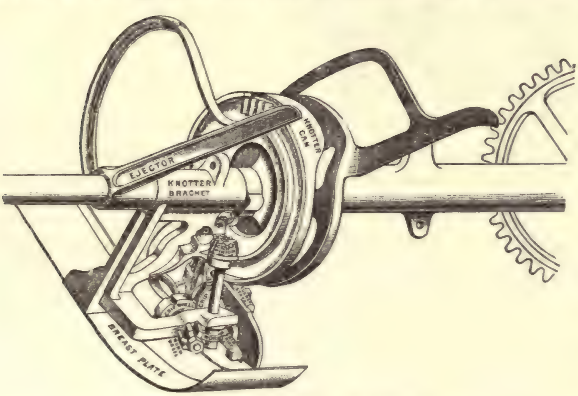


Fig. 13.—Knotter—driving parts.

All these movements, though serial, are performed so quickly as to appear simultaneous, but the nice timing of them for a virtually perfect result has been achieved, notwithstanding the difficulties arising from the rough jolting of harvest-work and the necessity of cheapness of construction. Figs. 13 and 14 show in some detail, from two directions, the mechanism that is above the table, and that is associated with the binding function.

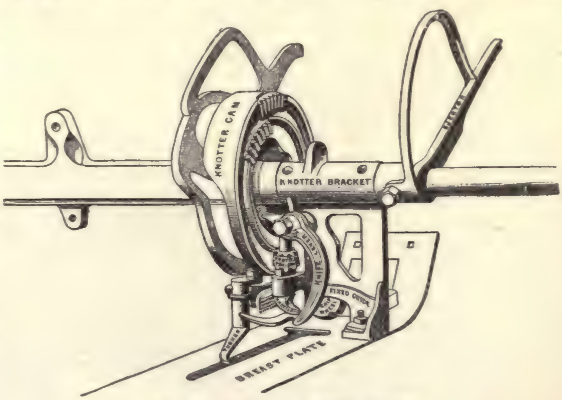


Fig. 14.—Knotter—driving parts.

Reaping Mechanism.—Fig. 15 shows the relation of the binder portion to the reaper portion of the machine. At the rear of the binder-table is a spring wind-board, restraining the heads of the moving grain. At the front is a hinged wind-board, adjustable by hand for controlling the butts of the grain, but this is often superseded by a small endless apron (Fig. 16),

driven on rollers supported on a flat frame placed on edge, hinged at the upper end and adjustable to different backward slants, by hand, in the same way, to suit varying lengths of

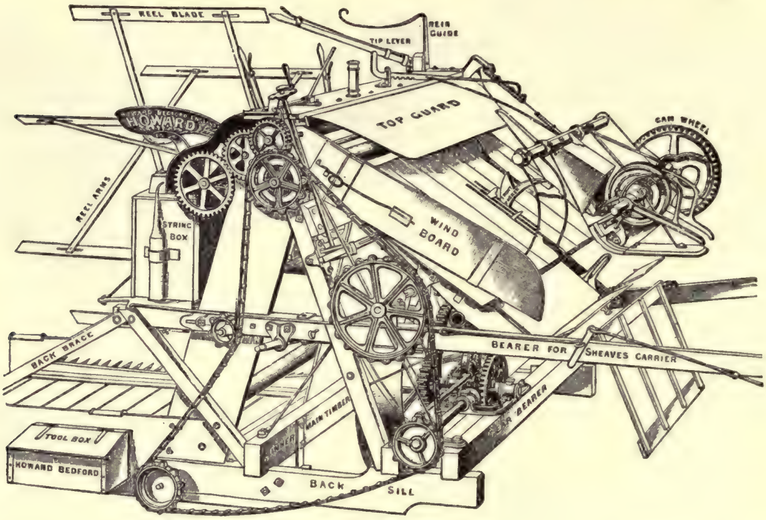


FIG. 15.—Reaping-machine.

grain (Fig. 17). Further, the whole binder combination is by a hand-lever, easily slid backward or forward, on rails fixed to the reaper-frame, to insure proper location for the band on the sheaf in grain of extreme variations as to length of straw. Chain-gear, arranged by McCormick (as in Fig. 18) is commonly used to convey power from a chain-wheel turned by a spline on the main binder-shaft under the binder. This chain drives all the binder mechanism. The driven chain-wheel at the top is fixed on the knotter-shaft and makes one revolution for each sheaf. It operates the knotter, ejector, twine-retainer, and cutter, and, by means of the connecting-rod shown, simultaneously rocks the needle-shaft below, to advance and withdraw the needle at the proper juncture to encircle the packed gavel with twine, present the twine to the knotter, and then open the way for the reception of more grain from the packers. The packers of this class of twine-binder run continuously, but the rear projection on the needle prevents them from taking hold of grain while the needle is up. At the end of each such revolution the entire binder mechanism, except the packers, is stopped automatically by a spring-shifter, one style of which (McCormick's) is seen in Fig. 19, and pauses, inoperative, until again tripped by pressure of incoming grain to repeat the single revolution necessary to bind and eject.

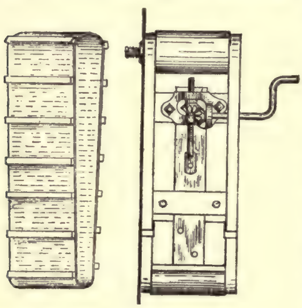


FIG. 16.—Carrier-apron.

The devices so far shown belong to what is known as the Appleby type of twine-binder, although similar practical results in automatically tying sheaves with twine are reached by some differences of mechanical detail in the Holmes binder, with equal success. Utilization of the mechanical pressure on a tripping arm, by the packed grain, to start the binder mechanism, is an essential of all the twine-binders in vogue, to relieve the operator from care over the binder routine. Once ad-

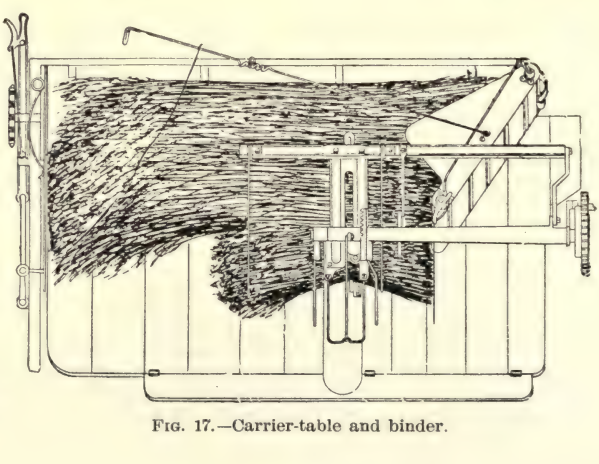


FIG. 17.—Carrier-table and binder.

justed for given tightness of band, position of band, and size of sheaf, the binder is self-regulating.

The Holmes Binder.—The knotter (Fig. 20) of the Holmes binder is a hollow shell rotated by its pinion and having a barbed volute hook centered on its lower end in a plane trans-

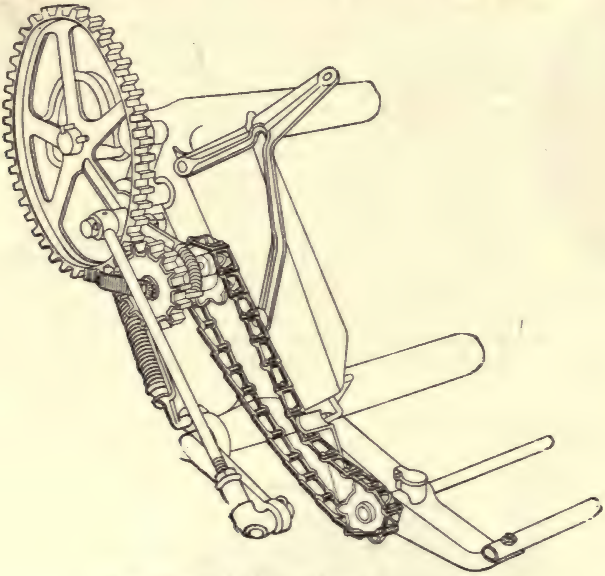


FIG. 18.—Chain driving binder mechanism.

versal with its axis. The shell contains a spindle carrying at its lower end a secondary hook accommodated to the bottom surface of the primary hook and normally in a state of pressure against the barb, held there by a spiral spring at the top connecting the spindle and shell.

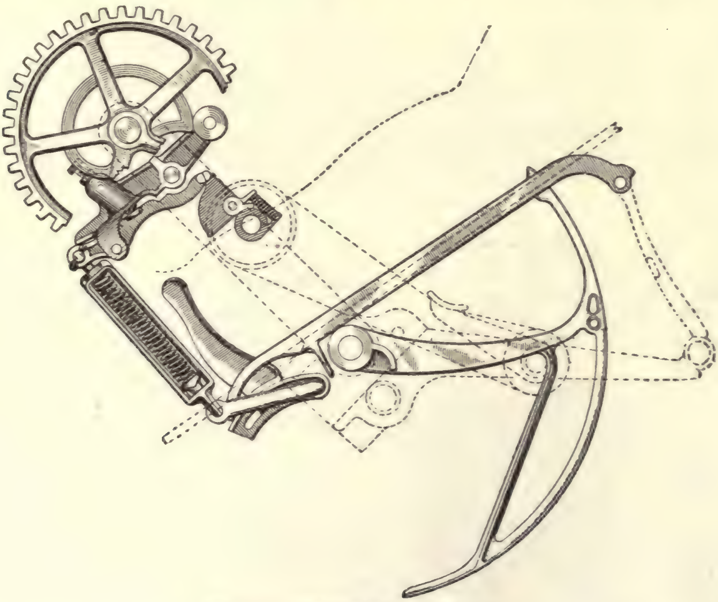


FIG. 19.—Spring-shifter and needle.

When the knotter rotates the top of its spindle strikes a stop just before the rotation is completed, while its shell, continuing to rotate, opens a gap between its barb and the end of the arrested secondary hook on its spindle. admitting the two branches of twine which are to be drawn through the turn of the knot (Fig. 21). The knotter then makes a retrograde revolu-

tion to its original position, during which the turn of the knot encounters a stationary stripper which plows the turn of the knot free from the hooks, while the ends, still pinched against the barb, are drawn through the turn to complete the knot. The ejection of the sheaf forcibly releases the knot ends from the barb. The device shown by Fig. 22 for retaining the twine end is a sliding grasper united with a stationary cutting blade, shown in progressive action in Figs. 23, 24, and 25. The relation of these parts and the cam-gear which drives them in unison is shown in Fig. 26. The spiral spring on the small lever which slides the grasper is arranged at such an angle as to equalize the holding power of the grasper on all sizes of twine; and the grasper swings from a pivot above it to render twine to the knotter positively, as the forming of the knot progresses. As this retaining device cuts off and seizes the twine end in one operation, and severs only one branch of the twine, it does not drop, unused, with each sheaf, the portion of twine gripped, as is done in the Appleby type; the flat coil form of the knotter also admits of bringing it down extremely close upon the straw, as seen in Fig. 27. Fig. 28 shows Wood's method of packing by an overhanging wheel armed with three folding packer-teeth, which withdraw successively from the grain when they have propelled it as far forward as possible. The automatic tripping device arrests the rotation of the two packer-wheels when it starts the operations of binding before described in the Appleby binder, and again starts their rotation each time the needle returns to its position of rest below the table.

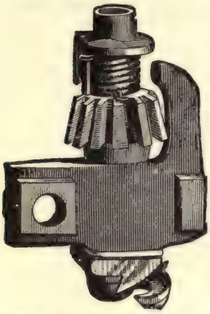


Fig. 20.—The Holmes knotter.

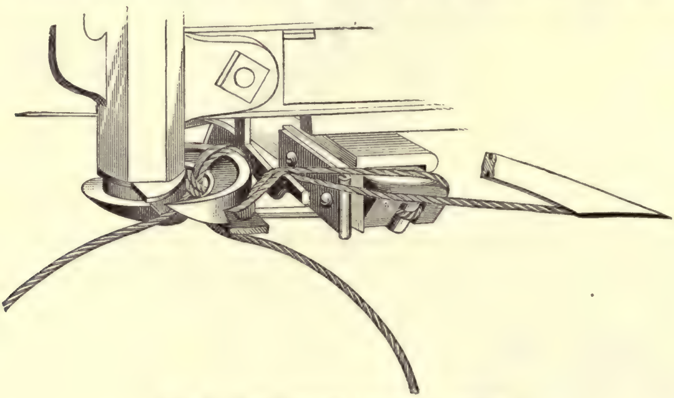


Fig. 21.—The Holmes knotter in position.

The ejector is swung by a crank to which it is pivoted about midway of its length, the top being pivoted to a hinged guide-rod, thus causing the two tines of the ejector to execute the

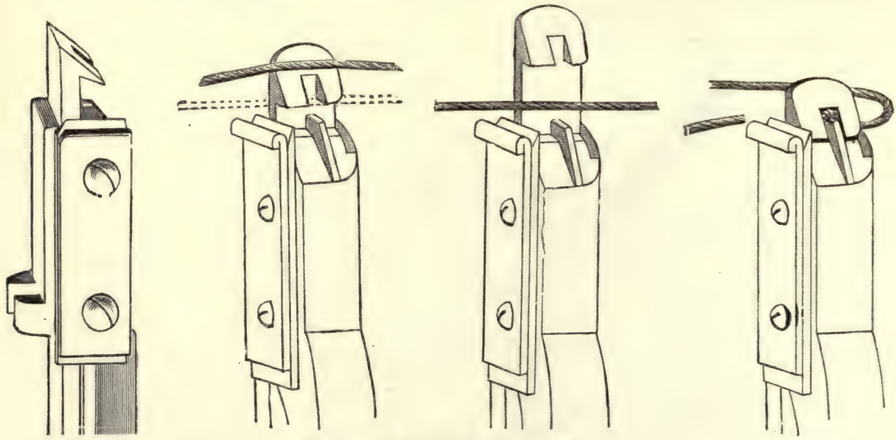


Fig. 22. Fig. 23. Fig. 24. Fig. 25.

Figs. 22-25.—Cutter, different steps.

movement of a pitchfork as ordinarily operated by the two hands of a man, as seen in the dotted line, Fig. 29. The direction of withdrawal avoids the tendency to foul discharged

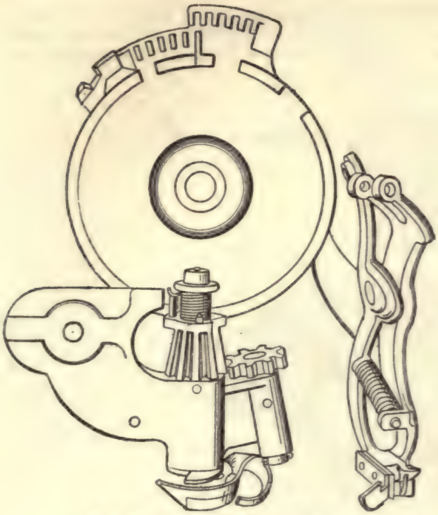


FIG. 26.—Knotter and cutter cam.

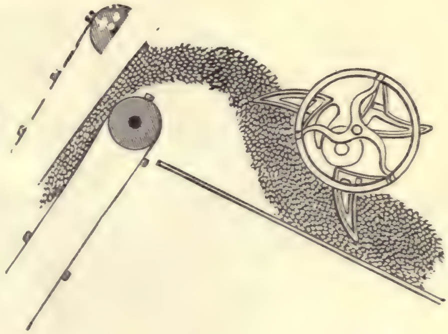


FIG. 28.—Wood's packer.

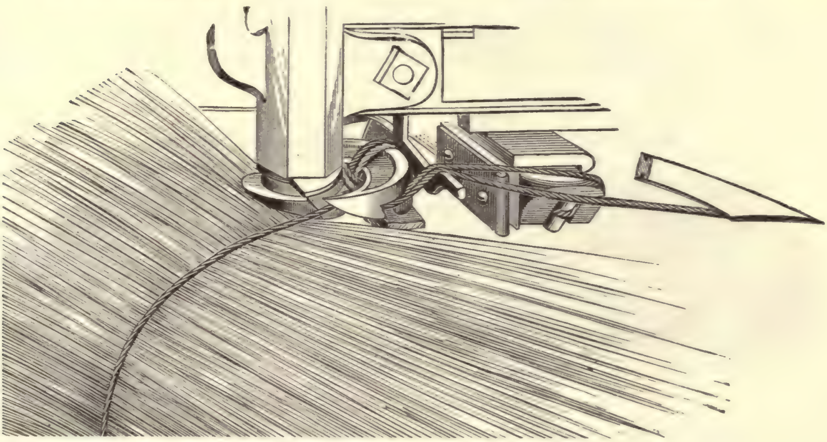


FIG. 27.—The Holmes binder in operation.

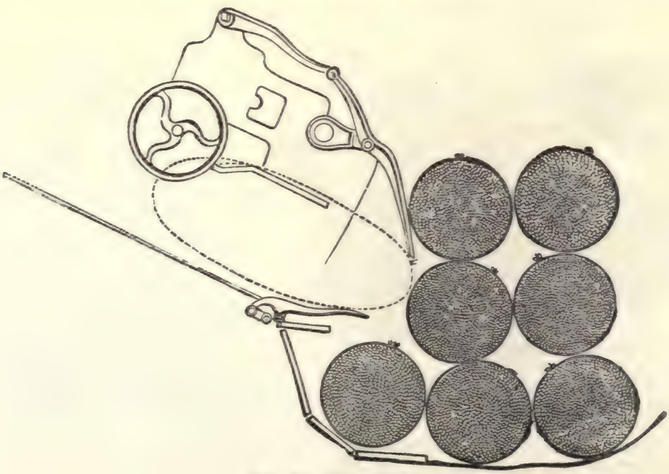


FIG. 29.—The ejector.

sheaves and carry them back over upon the mechanism of the binder, as may occur with a rotary ejector. The mechanism, except the needle when at rest, is placed above the table, and is seen in a general view in Fig. 30, which also exhibits a number of sheaves deposited on

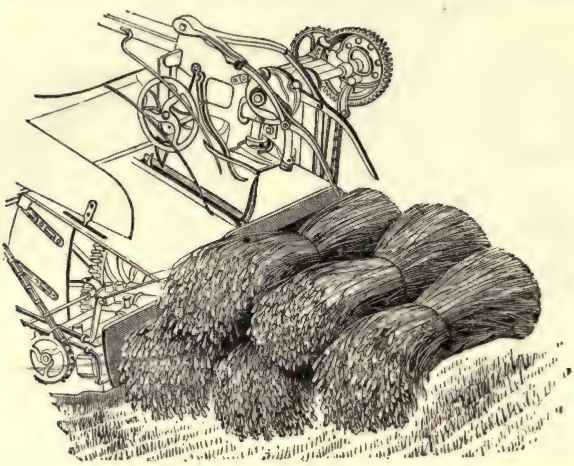


FIG. 30.—The Holmes binder complete.

Wood's sheaf-carrier. Fig. 31 shows the manner in which the sheaf-carrier folds backward, wing-like, to deposit its load. The operator can thus group his sheaves in such a manner as

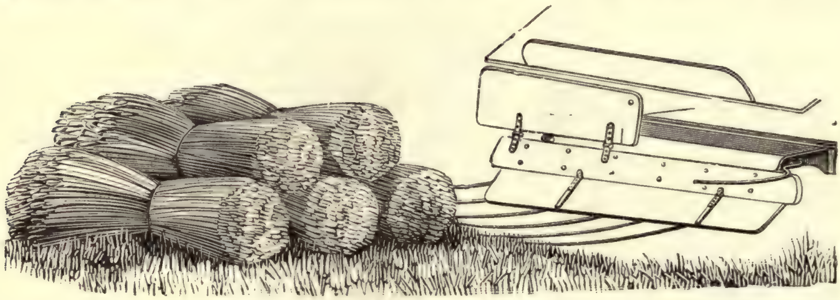


FIG. 31.—Sheaf-carrier unloading.

to greatly reduce the labor of stooking. Fig. 32 shows this binder with the back half of the table omitted. The packers and ejectors are in pairs. The pair of parallel bars in the table are adjustable higher or lower to determine the size of gavel. The automatic tripping is effected by grain pressure upward upon the tail of the trip-lever (Fig. 33), also seen in Fig. 30 to the

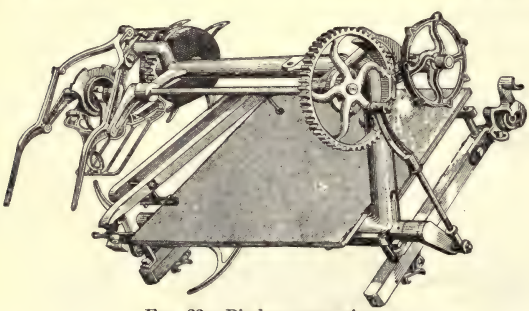


FIG. 32.—Binder—rear view.

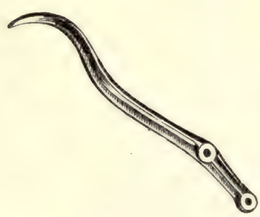


FIG. 33.—Trip-lever.

right of the packer-wheel. Figs. 34 and 35 show a manner of adapting the Wood machine to harvesting flax, which is usually left in bunches instead of sheaves. A slotted table with a series of teeth movable in the slots is substituted for the binder mechanism. The operator, by one movement on a foot-lever, unloads the sheaf-carrier and lifts the series of teeth to check the delivery of flax from the table as often as a sufficient bunch accumulates on the carrier.

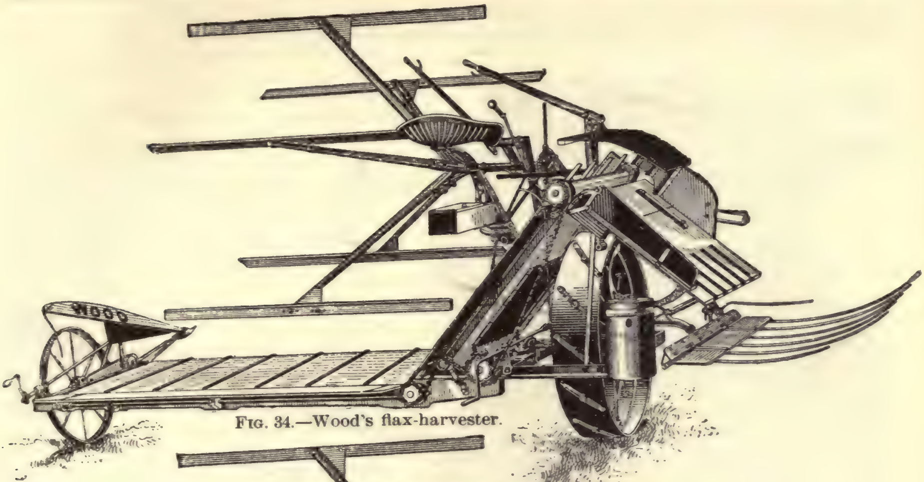


FIG. 34.—Wood's flax-harvester.

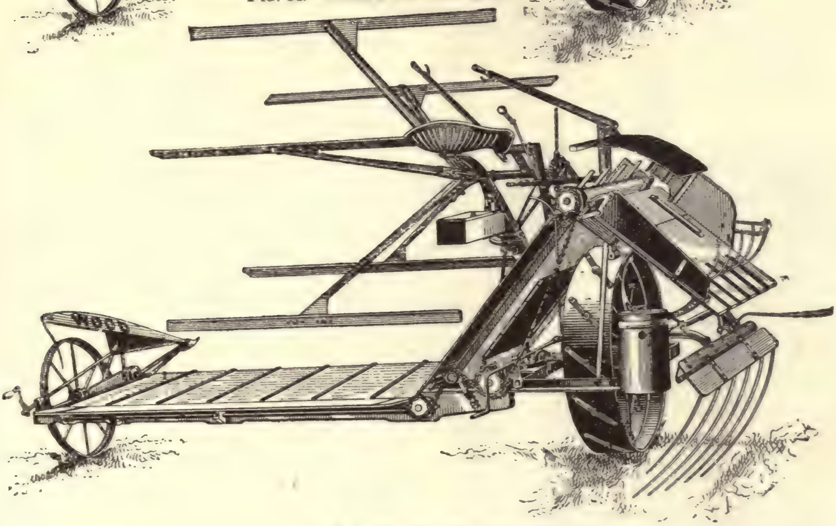


FIG. 35.—Wood's flax-harvester.

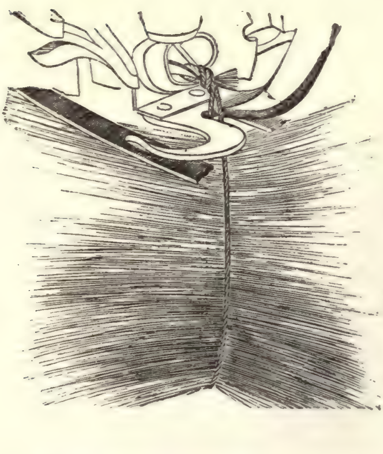


FIG. 36.—The Appleby knotter and sheaf.

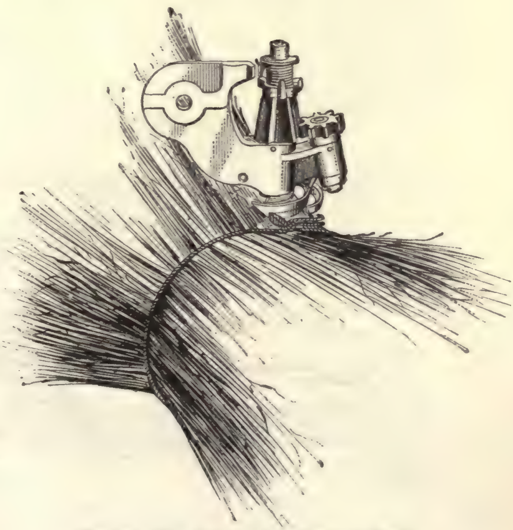


FIG. 37.—The Holmes knotter and sheaf.

The Appleby and Holmes types of mechanism are the only two in general use. Fig. 36 gives the Appleby with its sheaf about to be ejected, and Fig. 37 the Holmes knotter with the knot nearly completed, and its sheaf. Both depend somewhat upon the expansion of the sheaf, when relieved from compression, to insure a tight band; but the latter less than the former, because it makes its knot closer to the grain. Wood's (Holmes) binder squares the butts of the gavel with an oscillating board armed with several flanges to also move the grain downward, placed on edge at the front of the receptacle. The upper end of the board rotates in a plane coincident with that of the table, while the lower end receives a slight reciprocating motion from being linked to a suitably placed pivot; and the result is a series of rapid alternating raking strokes to move the grain downward from the elevator, on the table, and to square the butts (Figs. 38, 39).

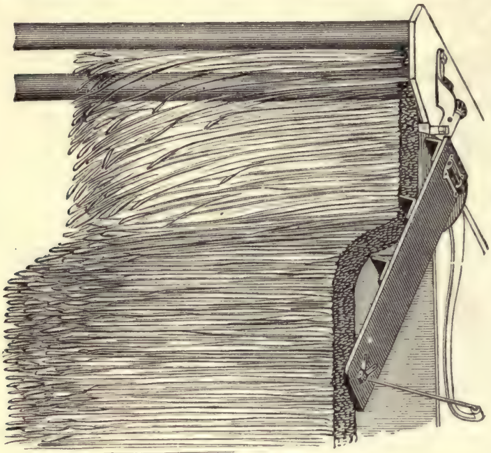


Fig. 38.—End board.

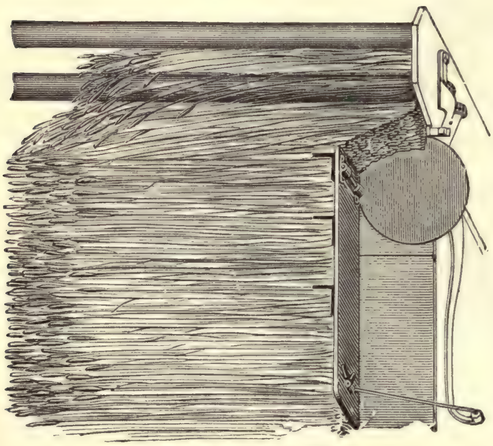


Fig. 39.—End board.

Features of the Wood binder not here described are so similar to corresponding features of the Appleby type that they do not need a separate description. The relation of the Wood binder to the harvester appears in Fig. 40. The harvesters used with the Appleby type of binder to do the reaping are, as a rule, triple-apron machines of the type formerly used with wire binders, and modeled on the original harvester invented by the Marsh Bros. to carry men with it at the side where the grain is delivered over the driving-wheel from an elevator, to do the binding by hand and drop their sheaves on the ground alongside. Wood has modified this harvester by deflecting the horizontal platform apron-conveyer and extending it up the elevator, and placing a lightly framed float upon the surface of the elevator portion to hold the ascending grain against the elevator to give pressure enough to force it up. To counteract a tendency of the moving apron to lift away from its proper place in the angle at the foot of the elevator, he drives all three rollers positively by suitable gear, thus drawing the bottom of the cloth tight and keeping the top surface slack. Lightness, reduced friction, and a decreased number of rollers and quantity of cloth are the objects.

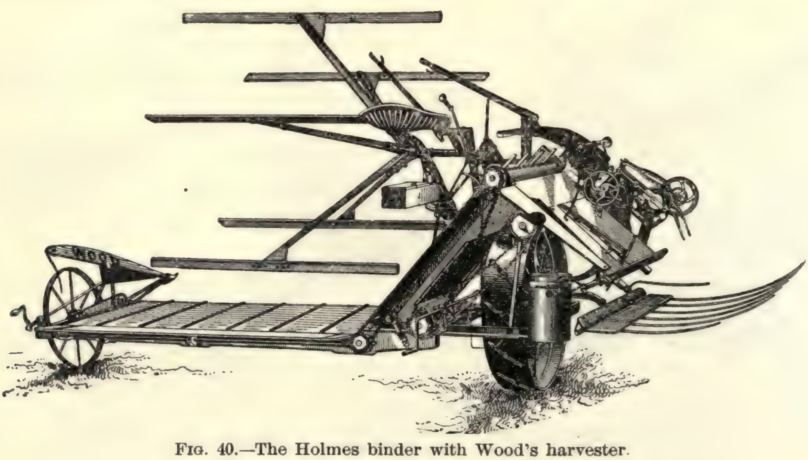


Fig. 40.—The Holmes binder with Wood's harvester.

The triple-apron and single-apron arrangements are outlined in Figs. 41 and 42. The operation of the single-apron construction is displayed in Fig. 43; that of the triple-apron

FIG. 41.—Triple-apron rolls.

FIG. 42.—Single-apron rolls.

construction in Fig. 44. For transporting this class of binding-harvesters on the road a stout two-wheeled truck is commonly used (Fig. 45), as the wheels of the machine track too widely for rural roadways and narrow bridges. For this purpose the tongue is made attachable to one end of the machine. So far as practicable, rolled iron or steel framework for

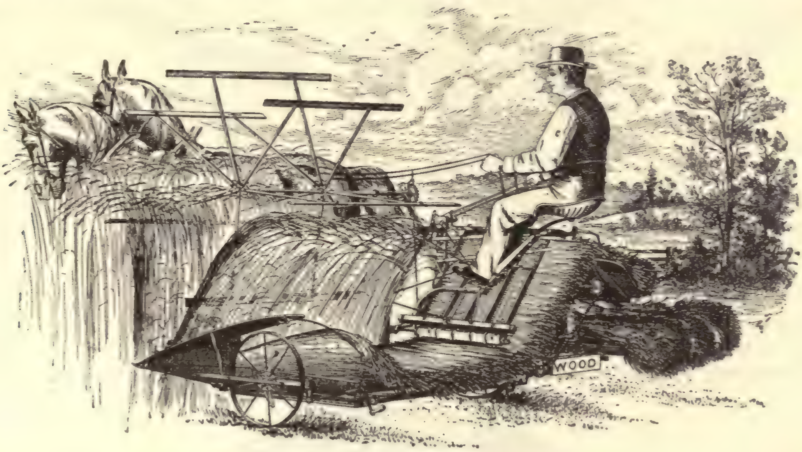


FIG. 43.—Single-apron operating.

binding-harvesters has superseded wood, to resist the effects of weather and maintain integrity of alignment. So, also, chain-gearing is employed when it can be made available, in

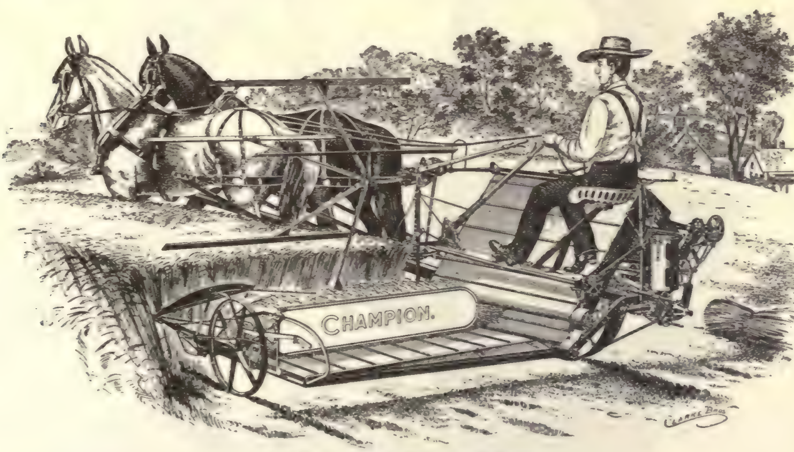


FIG. 44.—Triple-apron operating.

preference to cog-gearing, as it obviates the accurate lining of shafts, runs freely, and wears only in the chain-links, which are cheaply replaceable without delays, and its use lightens and cheapens construction.

Driving-Gear.—Fig. 46 is an improved arrangement of the driving-power by the Milwaukee Co. Fig. 47 is Shaughran's adjusting device for the harvester reel, made by McCor-

mick. At *a* is seen the right-hand portion of the reel-shaft. Its support is pivoted at *b* and *c*. The reel may be moved backward and forward by the hand-lever *d*, and upward and down-

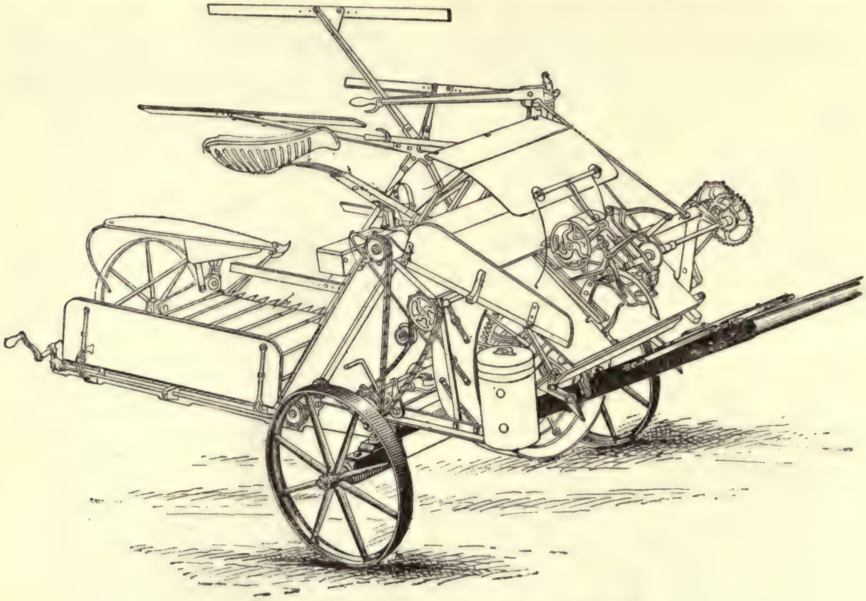


FIG. 45.—Wood's harvester ready for shipment.

ward by the hand-lever *e*, with their respective connecting-rods, to adapt the position of the reel in relation to the grain, the sickle-bar, and the conveyer which receives the grain. At *f* is a lifter-spring so attached as to sustain a greater portion of the weight of the reel and its

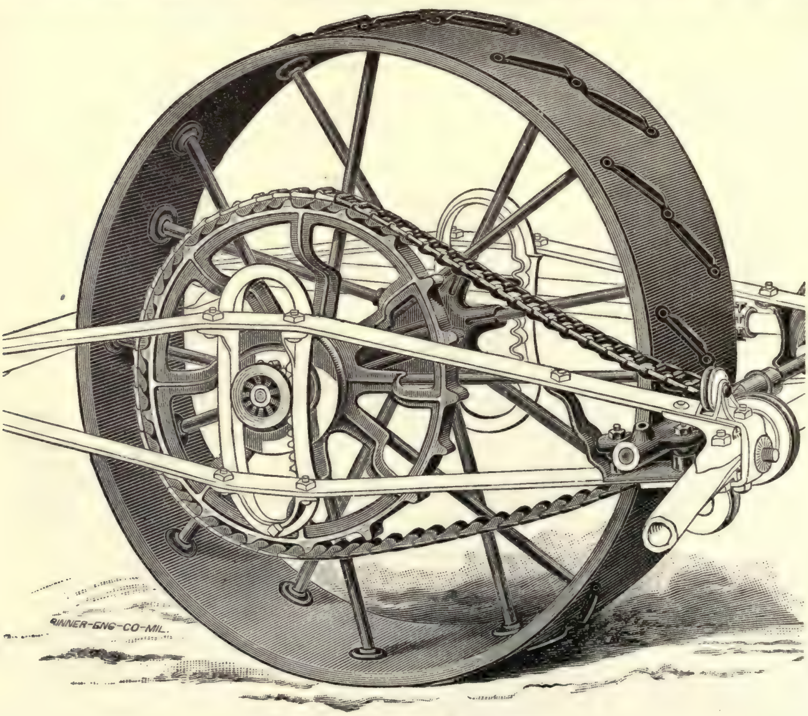


FIG. 46.—Milwaukee driving-gear.

support, to render easy the manipulation of lever *d*. The levers have spring-latches, and maintain the reel in any given position for the time being.

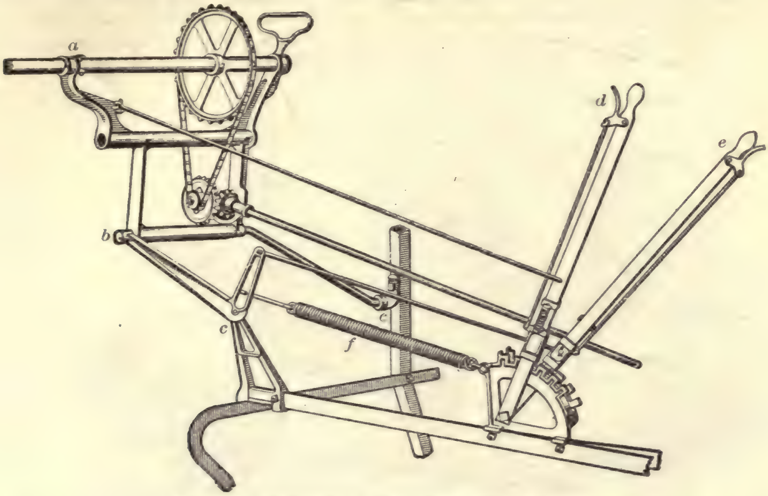


FIG. 47.—Shaughran's gear and adjusting device.

The Milwaukee Harvester Co.'s adjustable reel support (Fig. 48) has but one hand-lever, which locks the reel in any position forward or backward in the direction of its length, and

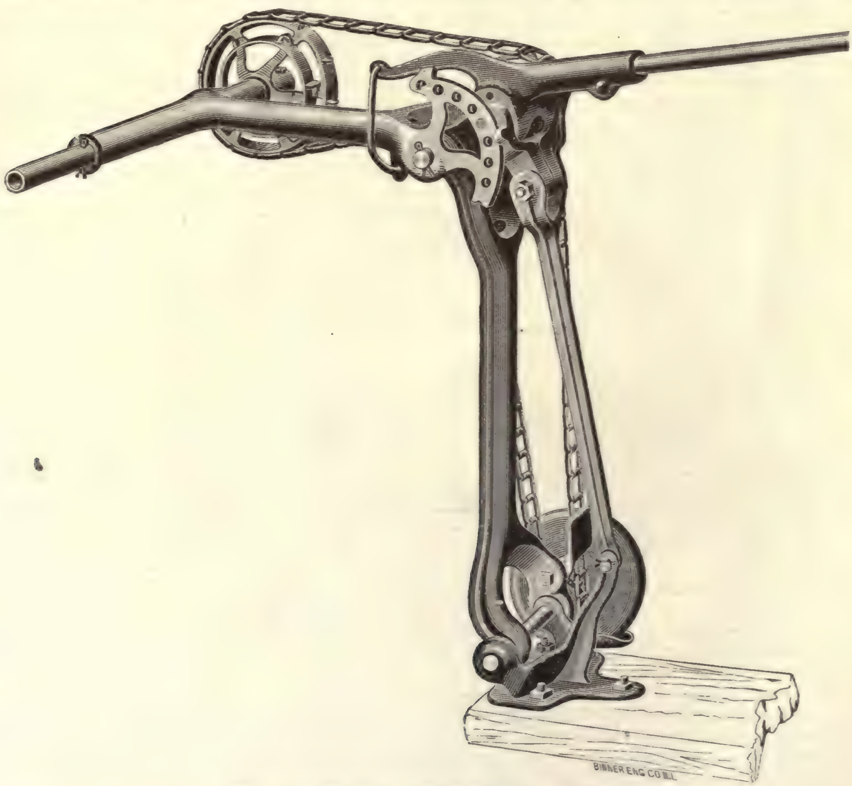


FIG. 48.—Milwaukee adjustable reel support.

upward or downward when turned on its own axis by the operator. A lift-spring in the forward arm, not visible in the figure, sustains the weight of reel and forearm.

Aultman, Miller & Co., of Ohio, make a binding-harvester (Fig. 49) in which the cloth con-

veyer is confined to the platform, and the grain is moved up the elevator to the binder under a suspended float carrying a pair of raking teeth, and by a gang of teeth with tedder action derived from a crank-shaft working under the elevator-boards. The teeth are propelled in slots in the elevator, and serve the double purpose of elevating the grain and packing it under the knotter, which is modeled on the Appleby plan. "This machine packs the grain upward. Walter A. Wood makes a rake-elevator binding-harvester (Fig. 50) which has cloth-conveyer

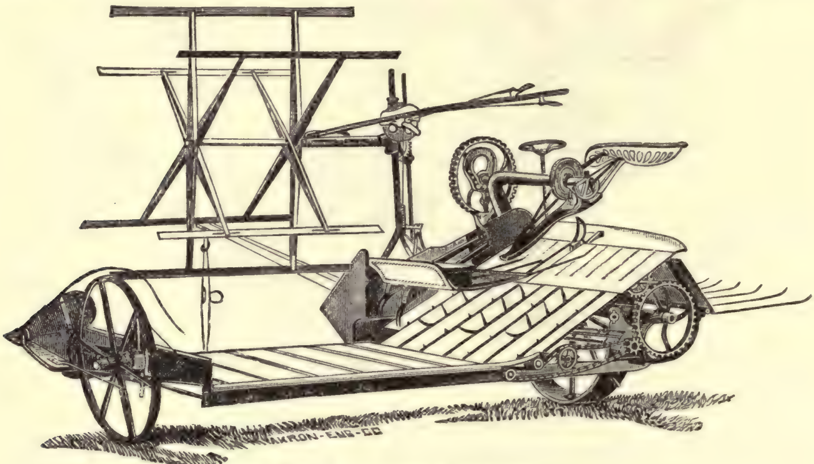


FIG. 49.—Aultman's harvester.

on platform only, and elevates and packs the grain with a rotary rake having teeth on four arms. The rake-heads rock, so as to feather and draw out of work, as soon as they arrive at the edge of the binder-table. They are held in work by tail-guides at the forward end. The raking device is in the form of a reel, which is journaled only at the forward end; thus the entire rear line of harvester and binder is left open, as seen in Fig. 51, giving unobstructed passage to the grain, however long the straw may be. There is a light cloth-and-frame extension behind the platform to keep the heads of tall grain from touching the stubble behind the harvester. The knotter works beneath the binder-table which is slotted just above it, and is a hook of the Appleby type. The twine-needle is pivoted above the space for the sheaf. The discharger reciprocates. The grain is elevated only along the small arc required for the action of the rake-heads upon it, lightening both weight and work. The driving-wheel is located just in front of the binder, not under it, as in other binding-harvesters, and its power is conveyed back to the binder, platform-conveyer, and elevator by a tumbling-rod. As the driving-wheel and grain-wheel are not centered on the same transverse line, the latter is arranged as a caster to avoid cramping in turning. It is attached far enough back to balance the machine, the principal weight of which is brought as near the driving-wheel as practicable. The weight of the tongue, and of the driver, whose seat is slightly forward of the driving-wheel center, on the hounds of the tongue, aids in balancing the machine."

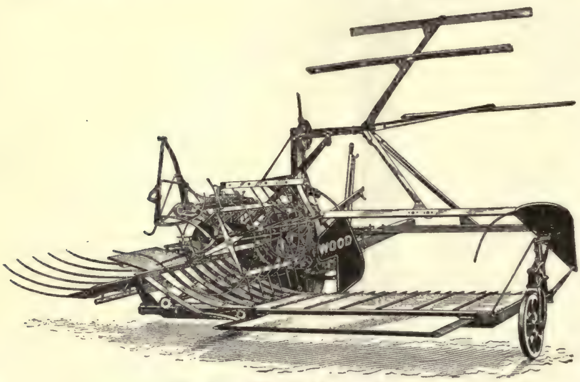


FIG. 50.—Wood's harvester.

A very considerable part of the harvesting in the large grain-fields of the Pacific coast is now performed with the wide-cut "header," sometimes drawn by a long string of animals, but preferably by a traction engine. The header cuts the straw near the top, leaving the stubble standing high, and taking off little more than the grain-ears. This renders the duty of the conveyer mechanism so light as to admit of taking a swath 15 or 20 ft. wide, and even wider. From the platform-conveyer the grain-ears are elevated between canvas belts to a point over the driving-wheel, and there shot into a long supplemental conveyer swung well out from the side of the machine to deliver them into large tender-wagons traveling alongside to receive loads and haul to the thrasher.

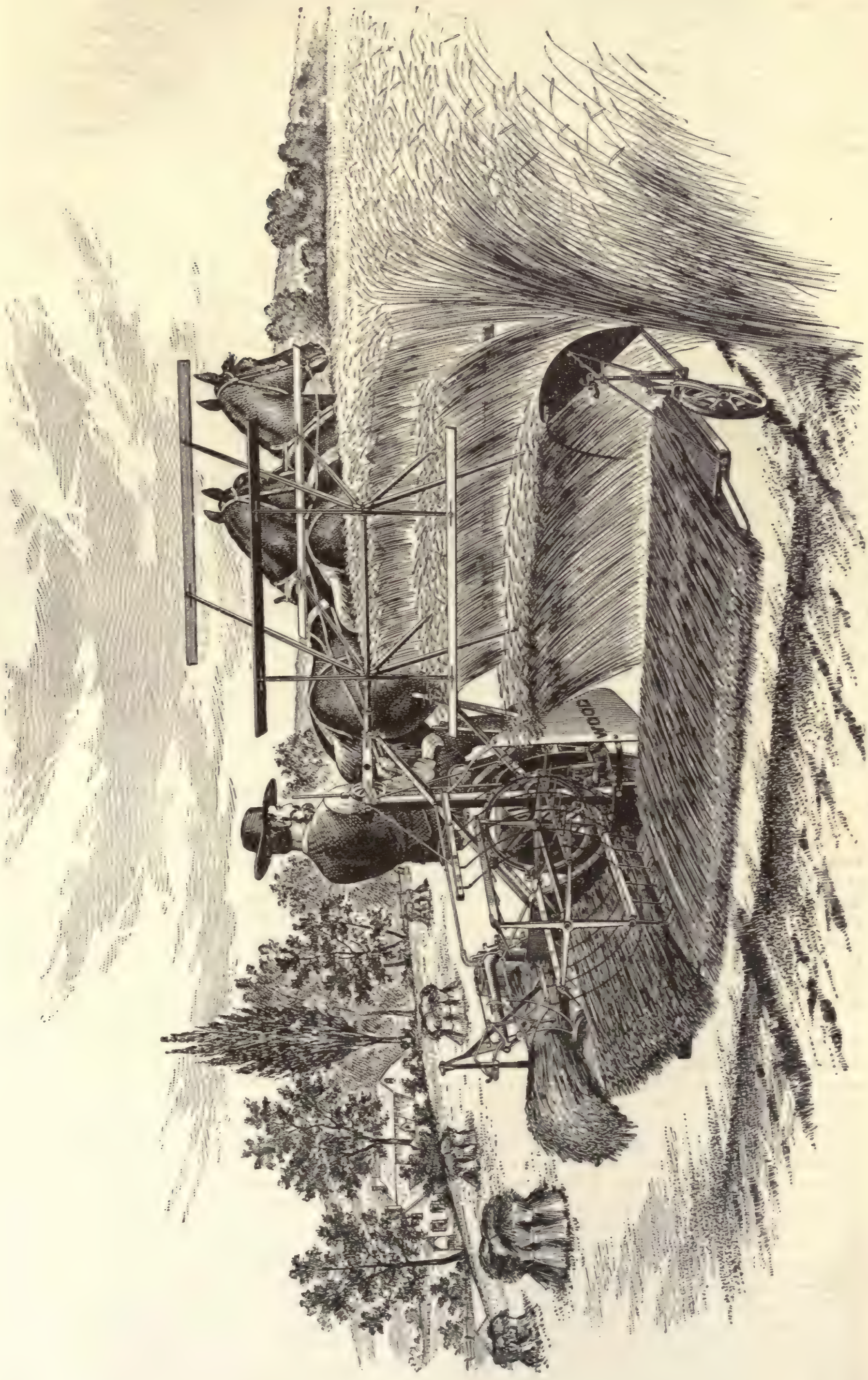


Fig. 51.—Wood's harvester—rear view.

A thrashing, cleaning, and separating attachment is carried on some of these headers. This elaborate mechanism is known as a combined harvester. Fig. 52 shows it as made by the Benicia Agricultural Works. It spouts the cleaned grain into sacks handled by men riding on the machine, who transfer it, ready for market, to the tender-wagon alongside as fast as the sacks are filled. The straw from the thrasher serves as fuel for the engine, which is made with a fire-box expressly designed as a straw-burner. This use of engines in harvesting, where farming is done on a large scale, the ground level and affording good footing for the engine-wheels under the influence of a steadily dry summer climate, is rapidly extending, having proved economical both in respect of money and time. Fig. 53 exhibits one of the wide-cut headers (Geiser's), with traction engine attached, in the field.

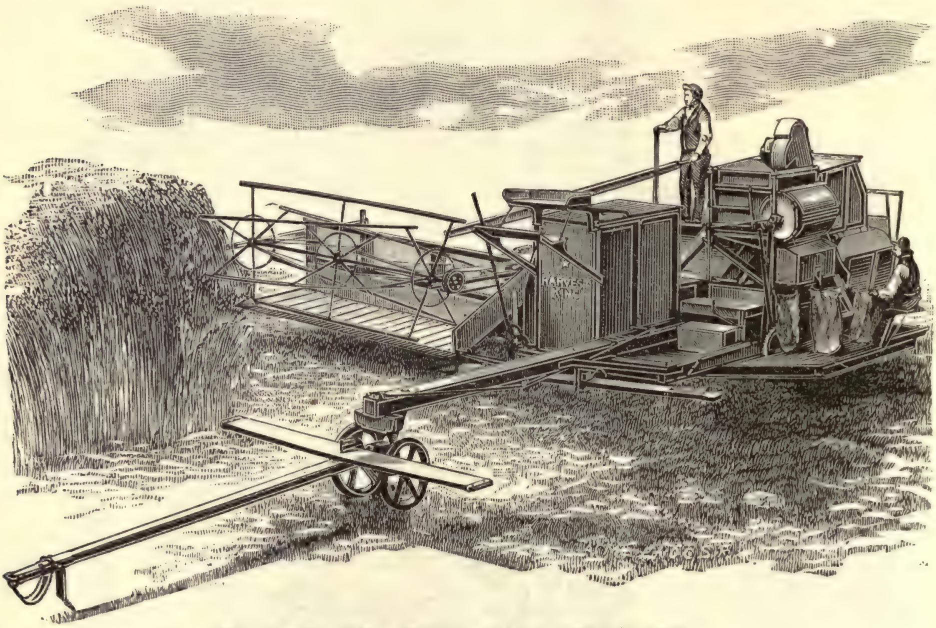


FIG. 52.—Thrashing, cleaning, and separating harvester.

Headers are sometimes employed in fields of small size in localities where straw is not valuable for sale. No binding mechanism is used in this mode of harvesting. The "Buckeye" harvester, for example, is adapted for use either as a header or binder. When used as a binder it is run low, bringing its sickle near the ground to cut long straw for binding into sheaves. As a header it is used with the binding mechanism off, and with the sickle raised high enough to merely clip the ears, and leave the straw standing in the field. Attached to the delivery side of the machine is an extension conveyer, the extremity of which is held at any requisite height by a rod controlled by the operator of the machine, and which is furnished with an endless apron to spout the harvested heads into an attendant wagon.

Corn-Harvester.—Fig. 54 is a sled with a folding wing each side armed with a blade set for work diagonally with the line of progression. The rapidity with which this very recently designed device has been adopted by farmers demonstrates the existence of a great need for corn-harvesting machinery. In this particular device the bladed wings are adjustable to whatever slant will cut off the corn-stalks most easily; when they are ripened to a point of dryness, a decidedly slanting cut is required. The blades, if serrate-edged, remain efficiently sharp a long time and do more thorough work than if smooth or knife-edged. Buck-saw blades are used. A lever serves to transfer the weight of the front end of the sled upon a caster-wheel beneath, when it is necessary to turn about at the ends of rows, in response to direction of draft. One horse suffices for draft. Two men ride the harvester, standing back to back, with a transverse hand-rail by which to steady themselves. The horse readily follows the proper line between the corn-rows, the reins being allowed to remain looped to the rail within easy reach. The men on either side receive the severed stalks in their arms until a gallows-hill is passed uncut by momentarily folding the adjacent wing of the harvester, when they set their armfuls in stook against the selected gallows-hill, resume position on the harvester, re-extend the folded wing, and proceed as before. A crank-lever below the hand-rail, moved by the foot, folds and extends the wing. Both wings are folded, for safety, when driving along out of work. Some of these sled machines are made with the deck adjoined to the runners adjustably, so as to gauge the height of cut. The attendants do not draw the stalks forcibly against the blades, but permit them to be slightly inclined forward, when the blades slice them off easily with a slant cut. While the invention seems simple, it has been a long time coming, and is

FIG. 53.—Geiser's wide-cut combination harvester.

FIG. 54.—Corn-harvester.

effective in light or only moderately heavy crops, of which 10 acres may be thus stooked in a day with labor which, though not arduous, accomplishes somewhat more than double the usual duty of two men working with corn-knives. A notable step in advance is a corn-harvester devised at the factory of the D. M. Osborne Co., at Auburn, N. Y. The cutters are two horizontal disk-knives turning toward each other. Spiked wheels turning on the same shafts with the knives force the corn-stalks between the knife-edges. The two divider-arms in front are spread open to receive the corn, whether standing upright or leaning, and are edged with toothed-driven endless chains to lift the corn and direct its tops backward just before it is cut off. The dissevered corn falls upon the lower end of an inclined carrier, essentially a series of toothed endless chains or belts suitable for elevating the coarse, heavy material some 8 ft. above the ground-level. An accompanying wagon receives the load, the corn being delivered on the wagon in two bents, one behind the other. The wagon-rack is necessarily low on the side next the harvester. To unload quickly, the right-hand wagon-wheels are lowered by running them in a trench prepared at the place of unloading, and the corn is rolled off at the side.

FIG. 55.—Bean-harvester.

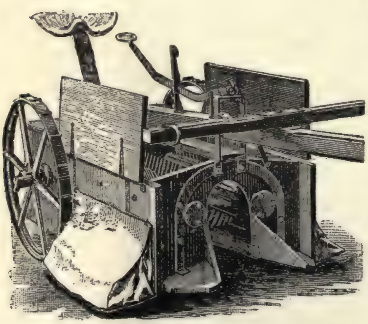


FIG. 56.—Pea and bean harvester.

Pea and Bean Harvester.—B. O. Savage's pea and bean harvester (Fig. 56) straddles the row and brings the peas or beans in contact with two revolving cylinders supplied with picker-teeth to comb the pods from the vines, shell the seeds, and deposit them in sacks. Five acres per day are claimed as its duty.

The "Moline" bean-harvester (Fig. 55) unearths the vines and lays the complete growth of two rows loosely in a windrow, ready to be loaded, midway between their original place, without shelling by any violent agitation.

HAT-MAKING MACHINES. *Stretching and Blocking.*—In the preceding volume of this work (Figs. 2301 to 2315) will be found illustrations of hat-stretching and blocking-machines which are operated by hand, and on which the work is manipulated by the operator. These machines have been materially improved, so that they are now automatic in their action.

The Tip-Stretcher has a ribbed and recessed former mounted on a vertical spindle and raised or lowered by a cam mounted on a shaft, which is revolved once only while a hat-body is stretched. This cam is so shaped that it will raise the spindle rapidly until the former and stretching fingers come into working relation. It is then gradually raised higher as the stretching progresses. When the stretching is completed the frame is lowered, and remains stationary long enough to remove the stretched hat-body and put another on over the former. In addition to this motion mechanism is provided which rotates the hat-body while the stretching is going on, and an absolutely uniform shaping of the crown is thus assured—a result not easily obtained in machines of the old type. The machine is capable of stretching from 20 to 30 dozen hats per hour.

The Automatic Brim-Stretcher operates in the same manner as the tip-stretcher. A hat-body, which has its tip already stretched, is placed upon the crown-block. The hat-body is raised to the stretching-fingers, and slowly rotated by mechanism similar to that employed in the tip-stretcher while the brim is developed. The machine is capable of stretching twice more hats than a hand-machine, and its work is much more uniform.

Blocking-Machine.—When a hat-body, which has been stretched on tip and brim, is blocked on a hand-machine, the operator has first to put it in the machine, and then clamp it at the edge of the brim. The band-ring has now to be brought and locked and the hat-block and brim-tongs simultaneously expanded, the one by a hand-lever and the other by a treadle. And, finally, when stiff hats are blocked, cold water is poured on to set the stiffening and thus fix the shape. All these operations are performed automatically in the machine shown in Fig. 1. When the hat-body is placed over the block, and in reach of the tongs, the ma-

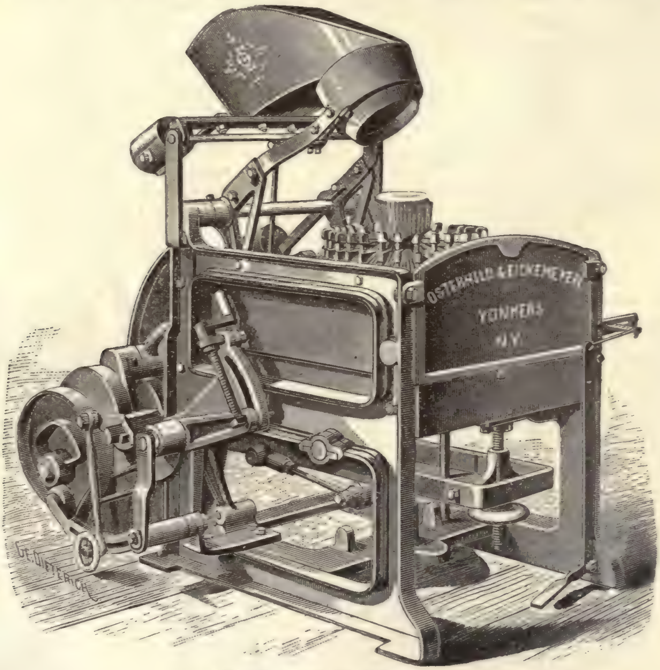


FIG. 1.—Blocking-machine.

chine is started by means of a foot-lever shown on the right and inside of the frame, and all the above-described operations are made automatically; and when the hat-body is blocked and cooled off, the machine stops and the hat-body is removed. It is evident that these machines do not require skilled operators. When once properly adjusted for a certain size of hat-body each performs its work upon the hat-body placed upon it.

Pouncing-Machines.—In former machines the hat-body, operated on by the pouncing material, has been exposed more or less to the danger of being wrinkled, and, consequently, injured in its passage through the machine. The apparatus has been improved so that the hat-body, which is fed by two small conical rollers, is always perfectly smooth, and the strain upon it while being pounced is reduced to a minimum. The wool-hat pouncing-machine differs from the fur-hat machine in the size of its pouncing-roller, which is 6 in., while the pouncing-roller of the fur-hat machine is only 3 in. in diameter. In both machines the hat

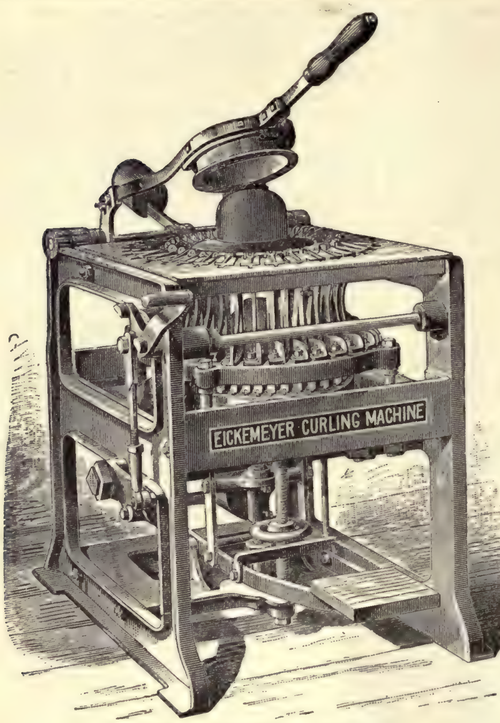


FIG. 2.—Curling-machine.

is supported on a metal button, held up by the operator with his right foot, while the feeding-apparatus is operated with the left foot. To cause the hat to run in or out it is only necessary to depress the foot-lever, which will operate the feed-rollers to a greater or less extent while the hat is being pounced. The facility with which a hat can be pounced is superior to anything heretofore attained. The fur-hat machine saves all blocking and handling of the hat. The hat is simply put in the machine, is pounced on the brim, and gradually run into the tip. During this time it remains smooth, and moving slowly, is not pulled out of shape; nor is the stiffening taken out of it.

Curling-Machines.—The operation of curling hat-brims has been greatly simplified by the introduction of automatic machines. The process, after the brim has been heated is as follows: Upon the horizontal table of the curling-machine (Fig. 2) are mounted 36 folding-fingers, which form a continuous ring around the edge of the hat. These fingers are movable toward the center by means of 10 treadle-levers, and are adjustable to any size or oval of the hat-brim to be curled. The hand-lever above the hat is pivoted in the rear of the machine, and on the band-ring a trim sheet-metal pattern of suitable size and shape is secured. This pattern is made in three sections of trim metal, and is held in place by springs which center it accurately over the hat-brim. After the pattern has been placed on the band-ring of the hand-lever the lever is lowered upon the table, and two adjustable fingers set within an eighth of an inch of the edge of the pattern, and confined in that position by means of the wheel-nut shown above the cross-bar on the treadle-lever. The hat, properly heated, is now placed on the machine, the hand-block accurately centered upon the chuck-block, and the edge of the brim resting upon the edge of the folding-fingers. The hand-lever is rapidly brought down, forcing the edge of the brim between the folding-fingers and the pattern, when, by the motion of the treadle, the former are made to move rapidly toward the center, folding the edge smoothly and evenly upon the pattern, when, by a turn of the hand-lever on the left of the machine, the folding-fingers are forced firmly upon the edge of the brim and thus complete the operation. The hat is now ready to have its inner edge trimmed. In order to insure accuracy the outer edge of the hat-brim is clamped upon a hat-supporting table (Fig. 3), and, to prevent any strain upon the brim, a rotary cutter is used to trim the edge of the curl. In the center of the revolving hat-supporter, which is mounted upon an adjustable oval chuck, a chuck-block of the same size and shape as those on the heater and curler is firmly fixed. Upon this the hat is placed. Twelve sections located upon radial sliding pieces are now closed around the edge of the brim by means of a hand-lever, and clamp the edge firmly. The rotary cutter shown in Fig. 3, on an inclined spin-

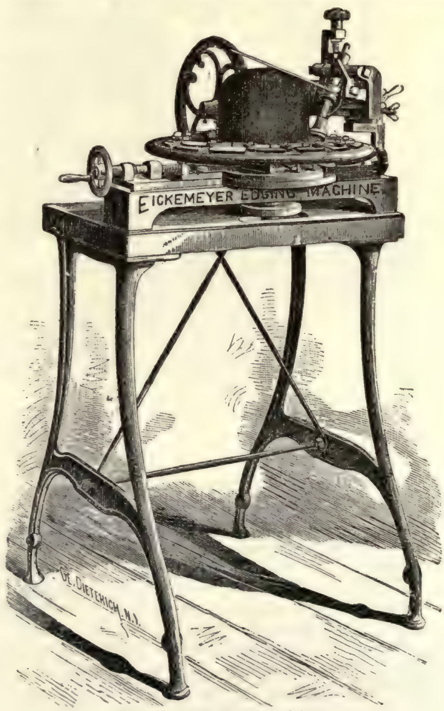


FIG. 3.—Edging-machine.

dle, is now lowered in place, and one or two revolutions of the hat-supporting plate is sufficient accurately to trim the edge. The machine is adjustable, and easily arranged for any oval that may be desired, trimming the curl to any width or shape.

The Blanchard Lathe in Hat-Making.—Many attempts have been made to improve the Blanchard machine so as to enable it to make flanges with scooped faces. It is claimed that the machine illustrated in Fig. 4 is the first in which this object has been successfully accom-

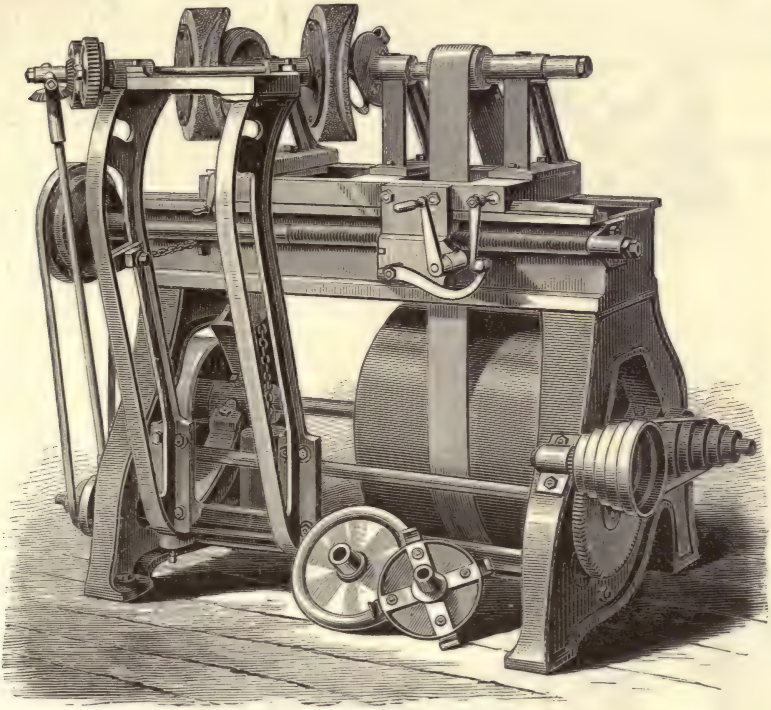


FIG. 4.—Blanchard hat-lathe.

plished. It will finish a hat-block from the edge of the band to the center of the tip, and it will cut out a flange flat or scooped ready to saw out the hole in the center, and will make any size of block or flange from a given pattern. In the machines heretofore used to make blocks, the pattern as well as the wood was held between centers, and it was impossible to work to the tip of the block. This made it necessary to finish every block made on the machine on a wood-lathe or by hand. Another point in the old machine was the adjustment of the machine to vary the sizes and heights of the hat-block to be used. Both of these points have, in this machine, been corrected. The hat-block is worked over by the cutter from the edge of the band to the center of the tips, and is ready for sand-papering when taken out of the machine. Only one adjustment is required to regulate the size and depth of a hat-block. In Fig. 4 the machine is shown as in use making a flange. The flange on the left of the machine represents the pattern, while the other represents the flange as turned by the machine. The pattern is secured upon an oval plate screwed upon the pattern-spindle, and the block of wood on a similar flange on the working-spindle; the saddle upon which the cutting-spindle and pattern-wheel are secured is now shifted to the left until the wheel touches the edge of the pattern. When the machine is started the pattern-wheel will cause the frame upon which the pattern and working spindle are supported to swing to and from the cutters, and an accurate copy of the pattern is made, the size of the copy depending on the adjustment of the pattern-wheel. Any style of flange or block can be made without other change than the substitution of one pattern-wheel or cutter for another. In Fig. 4 the pattern-wheel and cutter intended for such a block are shown as resting on the base of the machine. All the foregoing machines are from designs by and are patented to Mr. Rudolph Eickemeyer, of Yonkers, N. Y.

HATCH-OPERATING MECHANISM. Mechanism for causing the doors of hatchways in elevator-shafts to be automatically opened and closed by the movement of the elevator itself. The general arrangement of such mechanism is that, as the elevator-car ascends, it acts upon suitable levers whereby the hatch-door immediately in advance of it is opened. After the car has passed through the opening, the door, by similar means, is automatically closed. The object is to prevent a continually open shaft in buildings which might act as a flue, and hence increase the dangers of fire.

Hauling Engines: see Railways, Cable.

HAY CARRIERS AND RICKERS. *Apparatus for Transporting and Ricking Hay.*—Fig. 1 represents sectionally a form of hay-carrier made by the Janesville Hay-Tool Co. When held in position to receive a load, a key is retained in a trip-block by a pair of movable jaws until the fork-pulley rises, and with its registering-head forces them apart at the top, and allows the key to drop beneath and lock them. In Fig. 1 the carrier is shown as loaded, and the two jaws are held in position by the interposed key until the trip-block releases them by lifting the key, which is ribbed at its upper end to admit the forked edge of the trip-block and receive its lifting effect.

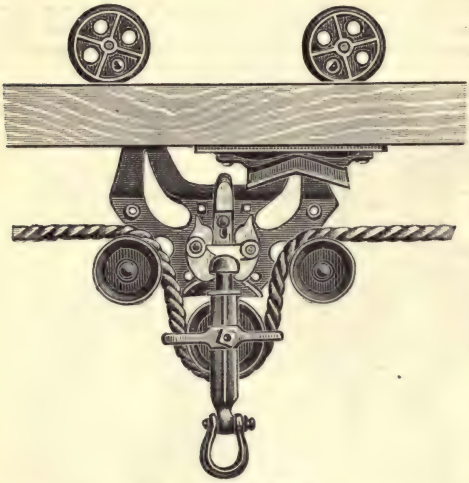


FIG. 1.—Hay-carrier.

Hay Forks and Slings.—Figs. 2 and 3 show the Janesville single deadlock, and Figs. 4 and 5 the Harris double harpoon-fork, both closed and opened. Fig. 6 is the Janesville wagon-sling. Several are used in each wagon-load of hay, laid at intervals, as the loading proceeds, to remove the load in any number of lifts determined on. It reduces litterings to a minimum. In Fig. 7 it is seen raising the final lift from a wagon. The hay forms a roll when lifted, and unrolls when discharged, as wide as the wagon-load was long, and in the same shape in which it lay in the wagon. Fig. 8 is a right-angle sling-pulley device by the same maker, adapted to work with the self-locking hay-carrier and the wagon-sling just described. It is hooked to the end rings of the sling, the hooks being separable for the purpose. As the rolling of the hay progresses, the pulleys mutually approximate until they meet, and the point of the single pulley enters the open space of the double one, where it locks. Both are then elevated together, until the registering-head engages the carrier-head. Fig. 9 shows an appara-

FIG. 2. FIG. 3.

FIGS. 2, 3.—Single hay-fork.

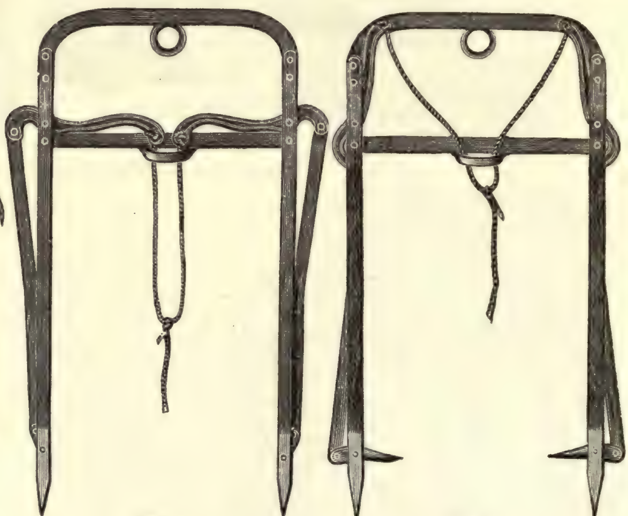


FIG. 4. FIG. 5.

FIGS. 4, 5.—Harris double harpoon-fork.

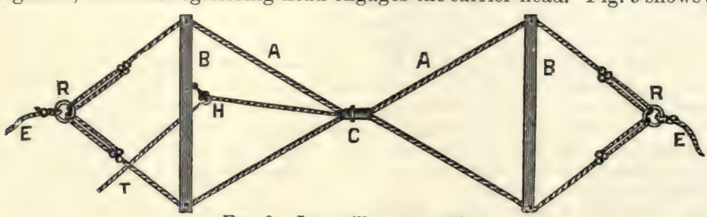


FIG. 6.—Janesville wagon-sling.

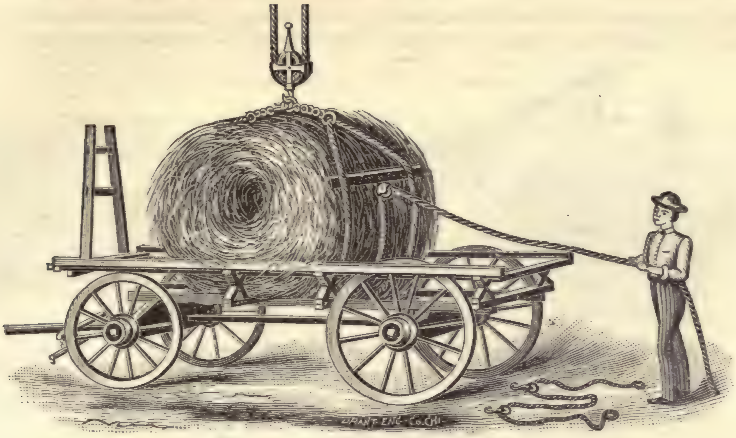


FIG. 7.—Janesville sling in position.

tus at work in a hay-barn. By the forward movement of the horse attached to the halyard, the fork-pulley *M* rises and engages the carrier *A*, when the latter grasps its registering-head, unlatches and moves freely along the track *H* until the attendant jerks his trip-rope *N*, when the load is discharged and the carrier returned to its original place by the operation of the counter-weight *R*, where it automatically locks. In locking, it frees the fork-pulley, so that the attendant can draw the pulley down with his trip-rope for a fresh charge of hay. The track may be prolonged as a davit outside the building, and the charges of hay introduced through an end-door at the gable.

FIG. 8.—Sling-pulley.

The "Acme" Hay-Gatherer and Hay-Raker (Fig. 10) are used in concert. With two of the gatherers or sweeps, and one of the rickers, the crop from 12 or 15 acres is stacked in a day by 4 persons and 5 horses. In operating the sweep a horse is attached at each flank, and about $\frac{1}{4}$ ton bunched from the windrow, or even from the swaths as left by the mowing-machine, and swept upon the ricker-head, a horse passing on either side, and the teeth of the sweep passing between the ricker-teeth and transferring the load to them. The horse attached to the hoist of the ricker, by means of a power-drum and pulleys, swings the ricker-head aloft on two long-hinged arms, which, arrested by a stop, pitch the hay forward upon the top of the stack. The rising of the ricker-head leaves space for turning the sweep about to drive away. A counter-weight aids in starting the ricker-head up-

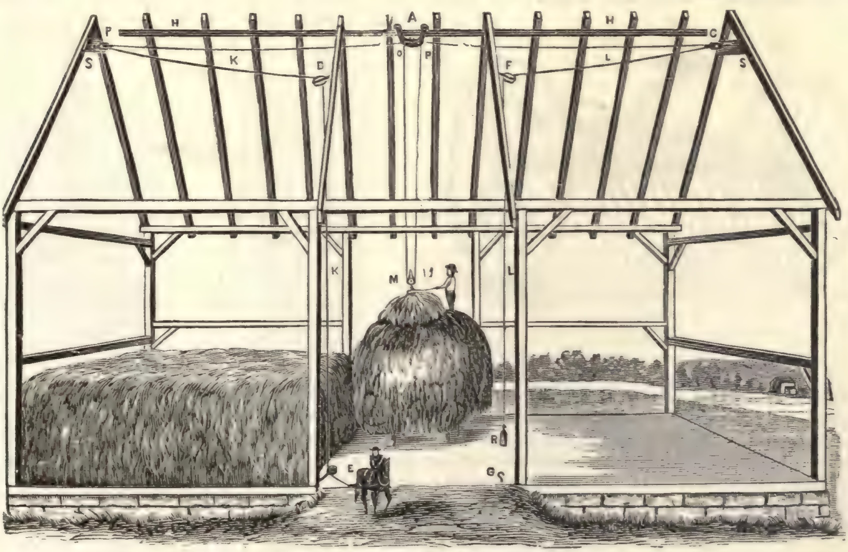


FIG. 9.—Loading or unloading hay.

ward when loaded and downward when empty. The sweep rides on two side-wheels and a rear caster, the latter supporting the weight of the driver, who controls the dip of the sweep-

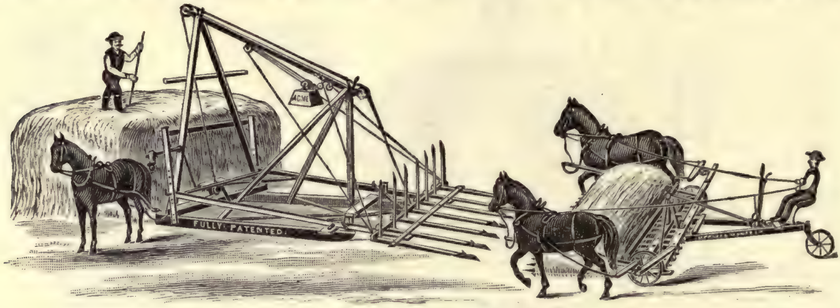


FIG. 10.—Acme hay-gatherer and raker.

teeth by a hand-lever. The ricker-stand may be moved on its runners by two horses along the side of the line of the stack, to make the stack of any length.

Hay-Fork Gatherer: see Hay Carriers and Rickers.

HAY-LOADERS. *The "Victor" Hay-Loader* (Fig. 1) is for loading hay into vehicles. It is of the class which is hauled at the tail of the hay-wagon, has an independent cog and chain driving-gear, actuated by its own ground-wheels, and may be shifted from one wagon to another in the field, as fast as the loading of each wagon is completed, by coupling its short tongue at the wagon-tail. Flexible-toothed rakes receive motion from a shaft provided with alternating cranks. These pick up the hay from the stubble and pass it to the end of the loading elevator, up along which it is propelled. The elevator is a series of long rods with their lower ends near the ground, where they receive a circular motion, and their upper ends over the wagon, where they receive a link motion. These rods are armed with teeth, disposed barb-wise, to force the hay up the incline of the elevator, and release the hold upon it intermittently after each upward impulse. This automatic loader takes the place of men to pitch the hay on the wagon from the ground, and at the same time saves gleanings.

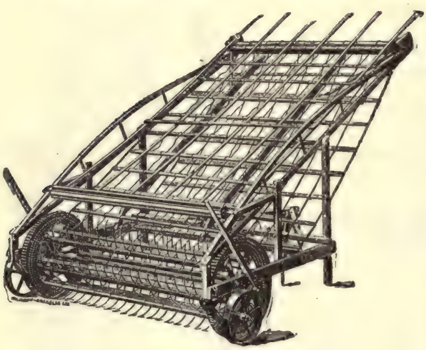


FIG. 1.—Hay-loader.

Hay-Press: see Presses, Hay and Cotton.

HAY-RAKES. *Apparatus for Raking Hay in the Field.*—Among the newer features in these devices are the following: The thills for sulky-rakes are arranged by several manufacturers so as to be quickly changed to a pole or tongue (Figs. 1 to 3), by drawing the bolts

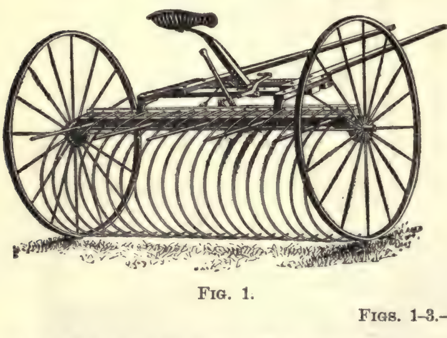


FIG. 1.

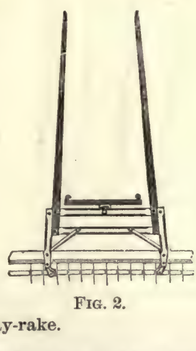


FIG. 2.

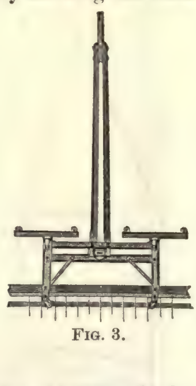


FIG. 3.

FIGS. 1-3.—Hay-rake.

which hold them in place, and rebolting them united midway of the hounds. An extra single-tree and a false pole-tip are supplied. Thus the rake is rendered available for either one horse or a span, and in an emergency the mower-team may be shifted to the rake. In many districts farmers rarely use a single horse for field-work—which makes this arrangement a desirable convenience, obviating the need of a special single-work harness for the hay-raking.

The Chamberlins Side-Delivery Hay-Rake is shown in Fig. 4. It rides on three wheels, the rear one a caster, giving triangular support and maintaining the operating axis parallel

with the surface of the ground at suitable height. One of the two forward wheels is connected by a chain-drive with a cross-shaft geared by cogs to an oblique intermediate shaft, chain-geared in turn to the crank-shaft, from which a set of four tedder-heads receive motion. Each tedder-head is armed with three tines. The crank-shaft being disposed at an angle of

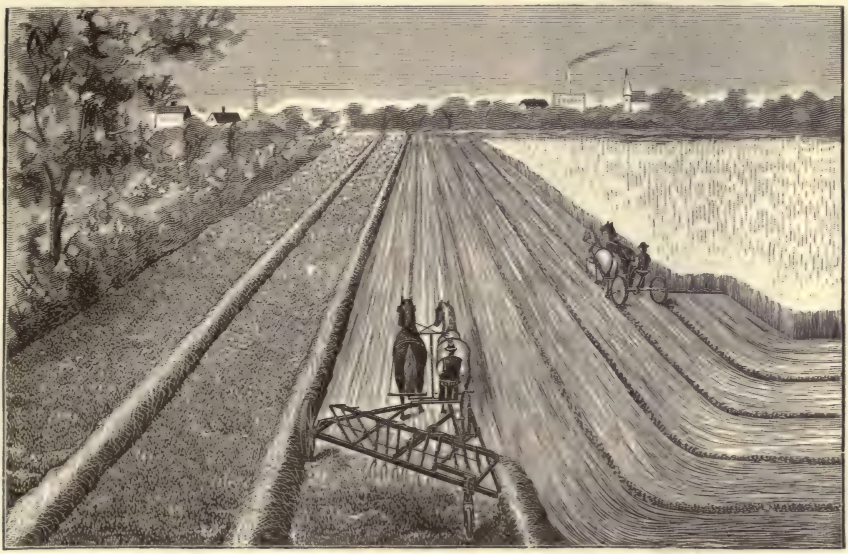


FIG. 4.—Side-delivery hay-rake.

about 45° from the line of travel, the tedders successively rake and pitch the swath-hay toward and finally beyond one side of the machine, continuously, into a loose, well-ventilated windrow, without rolling or compressing it. A strip some 10 ft. wide is windrowed without any manipulation from the driver. Two horses are employed. As it does not traverse the surface actually occupied by the windrows, there is a saving of distance to be traversed in any given field. This class of rake is especially advantageous for use in connection with the automatic hay-loaders of the class described in this article.

In the "*Keystone*" *Side-Delivery Hay-Rake* the axle is the main driving-shaft bevel-geared to a shaft with its axis in the line of travel. The latter shaft carries chain-wheels driving two rake-chains, which serially draw a gang of rakes, armed with curved teeth, transversely through the stubble, and transfer the mown hay from the swath into a raked windrow at one side of the machine beyond the wheel.

Hay-Sling: see Hay Carriers and Rickers.

Header: see Harvesting-Machines, Grain.

Heads, Exhaust Steam-Pipe: see Pipe-Heads.

Heater, Feed-Water: see Engines, Steam Marine.

HEATERS, FEED-WATER. *The National Feed-Water Heater* is shown in Fig. 1. It consists of a coil or series of coils of seamless drawn brass or copper tubes contained in an iron shell.

The Otis Heater is shown in Fig. 2. The exhaust steam enters the heater at the top, as shown in the cut, passes down one section of tubes into the enlarged space of the water and oil catcher, where the water of condensation and oil is separated, and the exhaust steam then passes up through the other section of tubes, thus passing twice through the entire length of the heater and heating the feed-water. The exhaust steam can then be used for other purposes or exhausted into the atmosphere. The water enters the heater near the bottom, and passing upward in contact with the heated tubes, gradually becomes thoroughly heated, and is discharged as near the top as practicable, so as to avoid carrying the scum that is on the surface of the water into the boiler.

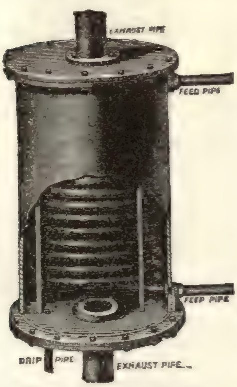


FIG. 1.—National heater.

FIG. 2.—Otis heater.

The Cochrane Feed-Water Heater and Purifier is shown in Fig. 3. Each side is formed of one or more ribbed plates, which are bolted together at the flanges, and the corners and

joints are packed with cement and rusted tight. The top and the bottom is each a single piece. Inside of the heater, and covering the steam inlet, is attached a separator, within which the oil is collected from the steam and conveyed away by a drip-pipe. The upper portion of the heater contains separate trays, which are inclined, and have several small ribs on each to distribute the water and retain solid substances. Opposite the separator, and a little below it, is a trough, connected by an overflow-pipe with the blow-off. Covering the outlet to the pump, and extending down toward the bottom, is a hood, which is open at its under edge only. Connecting the apex of this hood with the space above the water-line is a vapor-pipe, which serves to vent any gases liberated under the hood, and to prevent the water being so siphoned that the surface and any floating scum could pass under the edge of the hood.

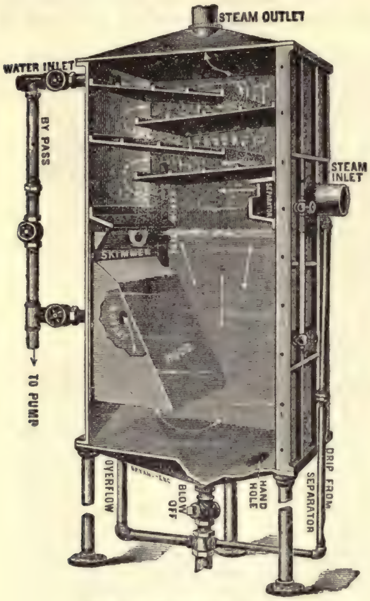


FIG. 3.—Cochrane heater.

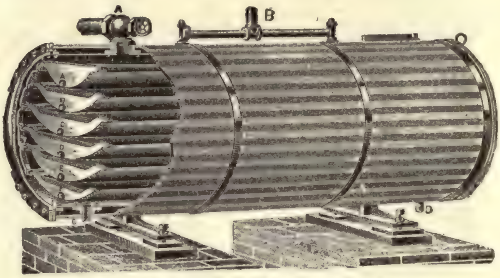


FIG. 4.—Hoppes feed-water purifier.

The Hoppes Feed-Water Purifier, shown in Fig. 4, is connected with the boiler by a pipe *A*, and the exit or gravity pipe *D*. A blow-off pipe is also connected with the purifier at *C*. The feed-pipe from the pump or boiler-feed is attached at *B*, and the water is distributed into the upper pans through the pipes leading into each pan. These pipes extend below the water-level of the pans and form a water-seal, which prevents the steam from getting into the feed-pipe and causing a water-ram. When the pan is filled the water flows over the sides a thin, uniform sheet along the bottom until it reaches the center, when it falls into the pan below, and so on over each successive pan until it reaches the bottom of the shell, from which it passes through the pipe *D* into the boiler. The water is heated to the boiler temperature, and parts with the scale-making substances it contains, the greater part of which adheres to the under side of the pans. While the purifier is in operation the pans remain full of water and afford settling-chambers for the heavier solids, such as mud, sand, etc., while the carbonates, sulphates, silica, and other hard scale-making substances adhere to their under sides.

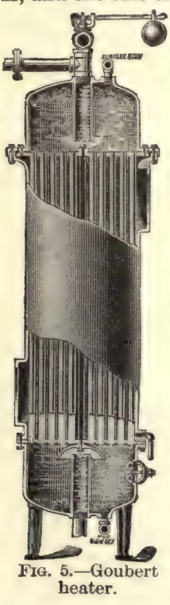


FIG. 5.—Goubert heater.

The Goubert Water-Tube Feed-Water Heater is shown in Fig. 5. It is essentially composed of two cast-iron water-chambers connected by a cluster of seamless drawn-brass tubes, rigidly secured at their ends to the tube-plates. The upper water-chamber is free to move vertically as the tubes expand or contract. The tubes are surrounded by a cast-iron shell provided with inlet and outlet nozzles, which are connected to the exhaust-pipes. The water inlet and outlet pipes are made to project inside of the water-chambers and opposite them are placed dish-shaped deflectors, the purpose of which is to deflect the current and thereby promote the separation of scum and sediment.

The Wainwright Heater is shown in Fig. 6. The exhaust steam enters at the opening *D* in the base, passing through corrugated tubes and out at the top through *C*. The water enters at the feed-opening *A*, passing up and around the tubes and out through *B*. The settling-chamber in the base is connected with the water-space in the shell. The blow-off opening in the settling-chamber allows the sediment which may have collected to be blown out in the bottom of the exhaust-nozzle of the base.

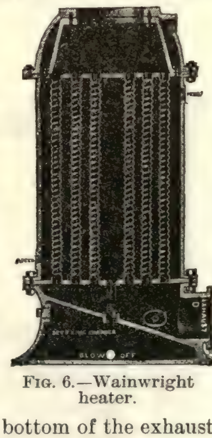


FIG. 6.—Wainwright heater.

Heating-Furnace: see Furnaces, Puddling and Heating.

Hide-Worker: see Leather-Working Machinery.

High Duty Attachment: see Pumps, Reciprocating.
High Grinding: see Milling-Machines, Grain.
Hoist, Air: see Air-Hoist.
Hoisting-Engine: see Engines, Steam Stationary Reciprocating.
Hoop Coiler-Driver: see Barrel-Making Machines.
Horse-Power of Boilers: see Boilers, Steam.

HORSE-POWERS. Fig. 1 is a perspective with cover removed, and Fig. 2 a sectional view of the Woodbury-Dingee mounted horse-power, made by Russell & Co., of Massillon, Ohio.

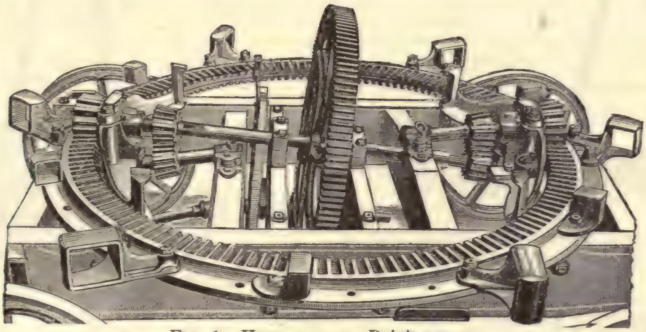


FIG. 1.—Horse-power. Driving-gear.

The master-wheel is socketed for bars for six spans of horses, with circular travel to rotate it horizontally. It is a double-crown gear, engaging four co-operating bevel-pinions driving an oblique shaft. On this shaft is fixed the large spur-gear that engages the pinion of the tumbling-rod, or knuckle-joint line-shaft. A pulley on this shaft (not shown in the cut) belts direct to the thrasher, or any other stationary farm machine. Fig. 3 shows the manner of installing the apparatus for operation. The tumbling-rod requires bridging where the horses pass over it on each round of travel. Horse-powers of this type are usually geared to drive the tumbling-rod at the rate of from 75 to 100 revolutions per min. Fig. 4 is the Packer upright horse-power. The position of the line-shaft aloft has obvious advantages, but at some sacrifice of firmness, and this device is often preferred for

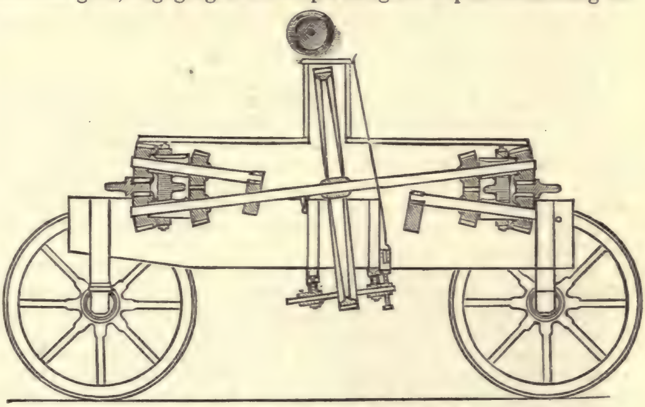


FIG. 2.—Horse-power. Section.

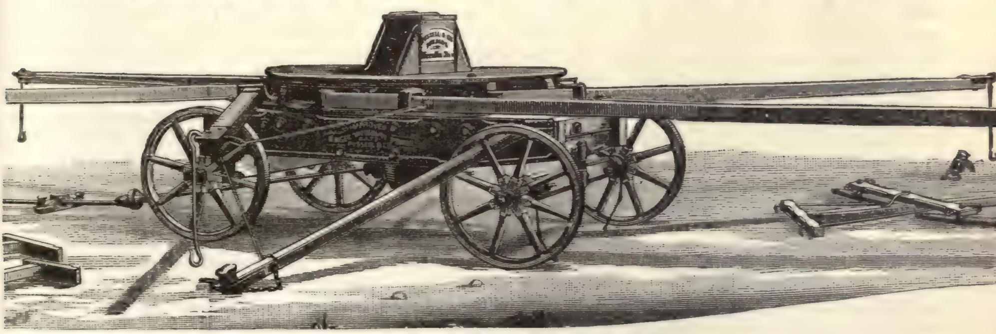


FIG. 3.—Woodbury horse-power in position.

driving the lighter kinds of stationary farm machines. The line-shaft may be swung around to any angle, and the animals used do not have their travel obstructed and their rate of travel checked intermittently, as is the case with "down" powers, when the animals step over the

tumbling-rod; there is also a gain in safety. The master-wheel, and all heavy parts of this type of power, are located on or very near the ground, for stability.

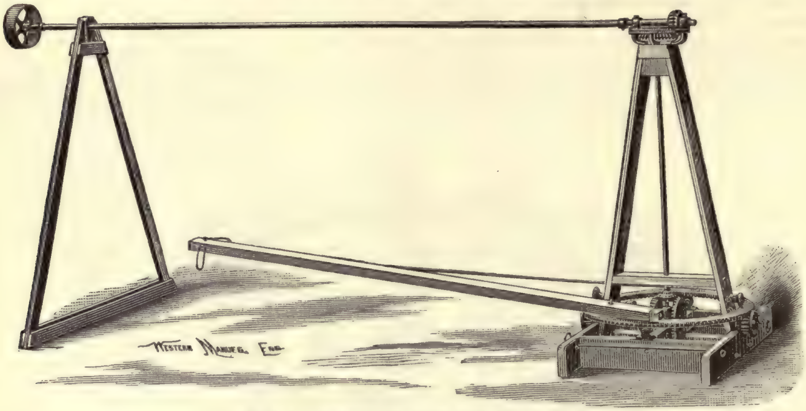


FIG. 4.—Packer upright horse-power.

Hose-Repairing Devices: see Fire Appliances.
Hot Water, Transmission of Power by: see Power, Transmission of.
Hub-Boring Machine, Turning-Machine; see Wheel-Making Machines.
Hub-Machine: see Mortising-Machines.
Husking-Cutter: see Ensilage-Machines.
Hydraulic Drilling-Machine; see Drilling-Machines, Metal.
Hydraulic Drill: see Drills, Rock.
Hydraulic Elevator: see Elevators.
Hydraulic Ram: see Engines, Hydraulic.
Hydraulic Transmission of Power: see Power, Transmission of.

ICE-MAKING MACHINERY. While there is considerable competition between manufacturers of ice-making machines and general refrigerating apparatus, there has been little change in theory and practically none in the chemistry of the art for some years, the main efforts put forth having been in the direction of avoiding complication in the working parts of the apparatus, reducing the cost, and establishing the utmost economy in power.

The two chief classes of ice-making apparatus are known respectively as "absorption" and "compression" machines.

ABSORPTION ICE-MACHINES can be built and operated at less cost than the superior types of compression apparatus, and it is further claimed in favor of the former that it is easier to pump the water of ammonia used in that machine than to pump the highly elastic, gaseous ammonia used in a compression machine. The comparison in the sizes of the two pumps is stated to be as 1 is to 500 in favor of the absorption process, not counting the additional trouble of keeping a gas-pump in good working order, but this is probably an exaggeration. Upon the other hand, it is asserted that out of the many ice-making plants which are known to have been abandoned, particularly in the South, the majority consists of absorption machines. The objections raised to the absorption principle are that there is not the same economy of fuel or water; that the action of the weak liquor will eat out pipe-work, necessitating frequent renewals of the pipe system; that it is impracticable to keep the ammonia in the evaporator-coils anhydrous for any considerable length of time, because the driers will become moist, and that expansion and contraction strains and opens the joints in the still and apparatus, and renders the plant wasteful of ammonia. Be all this as it may, this system has steadily increased the number of its advocates, and ice-manufacture is, commercially and mechanically speaking, making substantial headway.

In one of the latest improved absorption ice-machines, the ammonia-boiler contains in its lower half coils for heating water of ammonia, and its upper half contains the rectifier. The latter consists of a number of cast-iron pans bolted together, and arranged to form a zigzag passage through them, for gas passing up and rich liquor passing down. The extreme upper end of the boiler is connected by a pipe with the upper end of a coil in the condenser, which consists of an oblong iron tank open at the top, containing one or more coils immersed in water for condensing the ammonia. The outlets of the coils are connected with a collector, made up of a cylindrical reservoir closed at both ends, and having an external glass gauge to indicate the height of liquefied gas inside. This collector is connected at its bottom by a pipe with gas-exchanger, which consists of a closed cylinder containing a coil, the inlet of which is connected with the pipe from the collector. A pipe having a regulating-valve connects this coil with a manifold, to which is again connected a coil lying in a wooden tank, calked water-tight on the bottom and sides, and surrounded with a heat-non-conducting substance; this is called the "bath." This last coil is jointed at the upper end with the manifold. The tank contains a solution of salt and water. Partly immersed in this brine are the cans containing the distilled water, which is to be converted into ice. A lattice-work covers the top of the

bath, admitting the cans between its spaces, and a separate lid is also used. The outlets at the bottom of these last-named coils are connected by another manifold which is in turn, connected with the gas-exchanger. The outlet of the gas-exchanger is at the top, and is connected by a pipe with a coil in the distilled-water tank, which is round, of wrought iron, and closed at both ends; internally, there are two coils. The outlet of the coil connected with the gas-exchanger is connected with the absorber, which is a closed cylinder, containing one or more coils, through which circulates river or well water. The pipe from the distilled-water tank enters this absorber at the top, and extends down to within a few inches of the bottom. There is an outlet-pipe at the bottom, which extends to the bottom of the poor-liquor exchanger; this is also a closed cylinder, and contains a coil for partially cooling the poor liquor drawn from the ammonia-boiler. The outlet of this coil is connected by a pipe with the cooler, which is an iron tank open at the top, containing water and a coil immersed therein; the absorber is connected with this coil by a pipe having a regulating-valve. The inlets of the coils of the ammonia-boiler have a pipe connection with the steam-boiler, and the outlets are connected to a heater consisting of a closed cylinder containing a coil for heating feed-water for the steam-boiler, and condensing steam to make ice. The top of the heater is connected by a pipe to the top of the distilled-water tank. Gauges are employed for indicating the steam-pressure, ammonia boiler-pressure, and pressure or vacuum in the absorber.

The operation of this apparatus is as follows: Sufficient ammonia-water, 26° Beaumé, is pumped into the machine to fill the coil in the cooler, the exchanger, and the coil in it—the absorber until it shows in the gauge-glass, and the ammonia-boiler until it is up to the lower gauge-cock. Steam is admitted from the steam-boiler to the coils in the ammonia-boiler. This causes the gaseous ammonia to leave the water and ascend through the rectifier in the top of the boiler, and pass into the coils of the condenser; and under the combined pressure and temperature of the water surrounding the coils the gaseous ammonia turns into a liquid and runs down into the collector, the amount of liquefied gas being shown by the glass gauge on its side. The liquefied gas then passes through the coil in the gas-exchanger and out through pipes to the regulating-valve. Between this valve and the ammonia-boiler a continual pressure is kept up (depending on the temperature of the condensing water used in the liquefier). As the liquefied gas passes through the valve it passes into the pipe-manifold, in which a very low pressure exists, and consequently it expands and turns into gas again, producing a low temperature, varying from 4° below to 10° above zero, and as it circulates through the coils in the bath of salt water it absorbs the heat of the water in the cans through the medium of the salt water, and results in its being frozen. The gas passes out through the bottom of the coils into the manifold, and then into the gas-exchanger, and then comes in contact with the coil containing the liquefied gas on its way to the bath, and reduces its temperature. The expanded gas continues on out at the top of the exchanger, and passes on to the distilled-water tank, through a coil in the bottom, and cools the water used for filling the cans, the contents of which are to be frozen. The gas then continues on to the absorber, and passes down to the bottom, where it is reabsorbed by the poor liquor, or the same water from which it was driven out in the ammonia-boiler.

In order to cool the poor liquor so that it will reabsorb the expanded gas, it is drawn out from the bottom of the ammonia-boiler through the coil in the poor liquor exchanger, thence through the coil in cooler, where it is made of the same temperature as the river or well water, and thence into the absorber. Here the gaseous ammonia is readily absorbed by the poor liquor, which generates heat. The heat is carried off by water passing through the coils already mentioned. The now rich liquor passes into the pump, and is forced through the poor-liquor exchanger and then carried into the top of the ammonia-boiler, thence into the rectifier, where it meets the rich gas coming up, which its partially charged wih watery vapor, and partially freed from it by its contact with the rich liquor which passes down into bottom of the ammonia-boiler, and is now ready to go through the same process over and over again.

At the beginning of the operation, the steam that was admitted from the steam-boiler into the coils passes out in the ammonia-boiler to the heater partially condensed, but it does not furnish enough distilled water for the amount of ice the machine will make. The coil through which the feed-water passes to the steam-boiler is inclosed in the heater, and in passing through it condenses enough steam to supply the machine. The condensed steam is then conducted to the distilled-water tank and freed from the incondensible gases and cooled, and then drawn out to fill the ice-cans as occasion may require. The operation is continuous, one part not being delayed by another, but all moving together and at the same time.

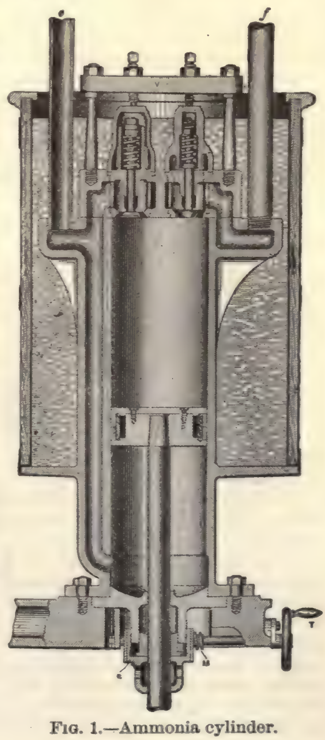


FIG. 1.—Ammonia cylinder.

The operation of refrigeration is performed in the same manner, with the exception that the heater, distilled-water tank, and the cans in which the ice is made, are dispensed with; the salt water in the bath is circulated through pipes in the apartments to be cooled, or, if preferable, the coils and salt water in the bath can be dispensed with, and the gaseous ammonia allowed to circulate through pipes in the apartments. A complete plant for the manufacture of ice consists of the parts enumerated above, with the addition of steam-boiler, water-pump, boiler-feeder, ice-truck, and dump.

Tests of Absorption-Machines.— Mr. Frederick Colyer, *Proc. Inst. of Mech. Eng.*, May, 1886, page 248, gives the results of a test of a Pontifex-Reece ammonia absorption-machine cooling 6,388 gals. (imperial gal. = 10 lbs.) of water per hour through 10° F. The condensing water used per hour was 1.320 gals. at 45½° F. The fuel-consumption was 100 lbs. of very common coal per hour. The steam-pressure was 50 lbs. per sq. in. The same machine, when employed for making ice, is capable of making 15 tons in 24 hours, if worked with three boxes, In the test, two boxes were used, making 10 tons. The coal-consumption was 120 lbs. per hour. or 192 lbs. of coal per ton (2,240 lbs.) of ice—11·7 lbs. ice per lb. coal.

COMPRESSION-MACHINES.—In the latest type of ice-making machine built by the Consolidated Ice-Machine Co. the compressors are set vertically, and are single-acting, compressing only on the up-stroke. A cross-section of the ammonia-cylinder is given in Fig. 1. The gas has free entrance to and exit from the cylinder below the piston, thus keeping the pump-cylinder and piston cool. The extreme lower portion of the pump forms an oil-chamber or reservoir, which effectually seals the stuffing-box. The suction and discharge valves are located in the pump-head. There are two cushioned discharge-valves, set in steel cages, which are held in position in the pump-heads by means of yokes and set-screws.

The suction and discharge pipe connections are made outside of the pump-head. All the gas is expelled at each stroke.

Tests of Compression-Machines.—An important test of a 75-ton compression-machine of the above-described type has been made by Prof. J. E. Denton, and is published in *Trans. A. S. M. E.*, November, 1890. The principal results are given in the following table:

Economy depending on Coal alone.

STEAM-ENGINE.			POUNDS OF ICE-MELTING EFFECT.								B. T. U. PER LB. OF STEAM.			
			150 lbs. condensing-pressure.				105 lbs. condensing-pressure.				150 lbs. condensing-pressure.		105 lbs. condensing-pressure.	
			28 lbs. suction-pressure.		7 lbs. suction-pressure.		Suction-pressure, 28 lbs.		Suction-pressure, 7 lbs		Suction-pressure.		Suction-pressure.	
TYPE.	Coal per horse-power.	Water per horse-power.	Per lb. of coal.	Per lb. of steam.	Per lb. of coal	Per lb. of steam.	Per lb. of coal.	Per lb. of steam.	Per lb. of coal.	Per lb. of steam.	28 lbs.	7 lbs.	28 lbs.	7 lbs.
Non-condensing	3	25	24	2·90	14	1·69	34·5	4·16	22	2·65	393	240	591	376
Non-comp'd condensing.	2·4	20	30	3·61	17·5	2·11	43	5·18	27·5	3·31	513	300	725	470
Compound condensing.	1·9	16	37·5	4·51	21·5	2·58	54	6·50	34·5	4·16	640	366	923	591

The above figures are equivalent to assuming a boiler efficiency of 8·3 lbs. of water evaporated per lb. of coal under working conditions.

For further reports of tests, see *Trans. A. S. M. E.*, vol. xi, for trials of a De la Vergne refrigerating plant.

Ammonia Condensers, which perform the work of condensing and liquefying the ammonia as it is discharged from the compressors, have the coils in which the condensation of the gas takes place immersed in a deep tank of water, and the heated gas enters the coils at the top of the tank, while the condensing water enters the tank at the bottom and overflows at the top. In this form, which is known as the submerged system, the hot gas from the machine first meets the warm water at the top of the tank, and as it passes toward the bottom of the coils gradually gives off its heat to the surrounding water, until it reaches the cool water at the bottom, where it becomes liquefied, and passes into the receiver. In an air-condenser the coils are not submerged, but water is trickled over the pipes, and both air and water absorb the heat of compression, and thus serve to condense and liquefy the gas. Efforts have been made in the direction of concentrating all the air in a high condensing pressure system in one place, where it may be discharged through a valve, and a fair measure of success has been attained. This is of great value, as the presence of air trapped at various parts of the apparatus has frequently required the evacuation of the whole system.

A Double-Acting Compressor is shown at Fig. 2. It is self-contained and horizontal, with the steam-engine that furnishes power for it on the same bed-frame, the piston-rods of both gas-cylinder and steam-cylinder being in a direct line from center to center. The wrists connecting the driving-rods with the cross-head and with the wrist-pins on the outside of the fly-wheels, avoid the wear and tear inevitable from the ordinary crank and fly-wheel system. By a special arrangement, consisting of a chamber formed in the stuffing-box, and a pipe or pipes leading from it to the suction side of the gas-cylinder, the pressure on the stuffing-box around the piston-rod, as it comes out of the gas-cylinder, is equalized with the back pressure from the expansion-coils, which pressure usually ranges from 15 to 25 lbs. to the sq. in. Another

device dispenses with the use of water as a means of cooling the piston-rod, this being done by a constant flow of oil through an oil-chamber built on the gland of the stuffing-box itself.

A third improvement made by the inventor (John Ring, of St. Louis) of the above machine, and embodied in his ice-making system, is based upon the fact that the ammonia goes through the expansion-coils, in actual work, so rapidly that at the outlet it still has in it the capacity of further absorption of heat. After leaving the coils the gaseous ammonia goes to one or more receivers, where a further compression is produced by simply arranging the outlet-pipes so that their area will be slightly less than that of the inlet-pipes. When expanded into other coils beyond the receiver, the gas can be utilized to cool the distilled water in ice-making, and additional rooms in refrigeration.

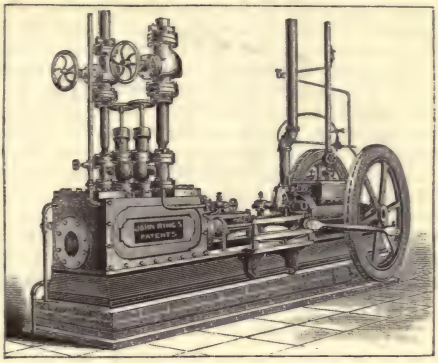


FIG. 2.—Double-acting compressor.

Cold Storage. — For storing perishable goods at temperatures above or below the freezing-point, and making ice in connection with the same, a useful combination is formed in the plant produced by an English Cold Storage Co., and called "Hill's Refrigerating Apparatus and Dry-Cold Air-Chamber."

The apparatus consists of: (*a*) An ammonia-boiler, separator, and condenser with connections, for producing the cold. (*b*) A refrigerator or cold chamber, with non-conducting walls, the roof of which is formed by a tank containing a non-congealable liquid which can be reduced to any required temperature down to 70° F. below the freezing-point. The working involves no risk. A slow-combustion stove is required containing a coil for the rapid generation of steam, which is used to convey heat to the ammonia-boiler. Steam can be raised by the use of coke, gas, spirit, or oil; or, if a steam-boiler already exists, then steam may, of course, be taken from it.

The cold is produced as follows: (*a*) By the distillation of ammonia-gas from water in which it is held in solution. (*b*) By the conversion of dehydrated gas by automatic pressure into liquid anhydrous ammonia. (*c*) By the automatic evaporation (under control) of the liquid anhydrous ammonia. (*d*) By reabsorption of the gaseous ammonia in the water in which it was originally held in solution.

By the third stage of the operation (*c*) the latent heat is extracted from the bulk of the liquid anhydrous ammonia and the sensible heat from the cold-storage bath. Intense cold is thus produced in and stored up by the said bath to the desired degree of temperature (either above or below freezing). The tank containing the cold-bath forms the ceiling of the cold-chamber, and, being of the same temperature as the bath, abstracts the heat from the air in the chamber, and as the coldest air falls to the bottom of the room, the warmer air, rising to fill its place, is in its turn cooled, and, falling, a constant circulation is automatically kept up; at the same time the air is dried by freezing out the moisture ordinarily contained in it—a feature which presents advantages when dealing with the storage of perishable articles of food. The cold-bath liquor and ammonia, the only chemicals used in the process, suffer practically no waste, and neither of them come in contact with the contents of the cold-chamber. Any degree of dry cold can be obtained; and a reserve of cold can be stored up and given out automatically as required.

A valuable paper and discussion on refrigerating and ice-making machinery and appliances appear in *Proc. Inst. of Mech. Engrs.*, May, 1886.

INDICATORS, STEAM-ENGINE. *The Tabor Indicator* is shown in Fig. 1. The special peculiarity of the Tabor indicator lies in the means employed to communicate a straight-line movement to the pencil. A stationary plate containing a curved slot is firmly secured in an upright position to the cover of the steam-cylinder. This slot serves as a guide and controls the motion of the pencil-bar. The side of the pencil-bar carries a roller which turns on a pin, and this is fitted so as to roll freely from end to end of the slot with little lost motion. The curve of the slot is so adjusted, and the pin attached to such a point, that the end of the pencil-bar which carries the pencil moves up and down in a straight line, when the roller is moved from one end of the slot to the other. The curve of the slot just compensates the tendency of the pencil-point to move in a circular arc, and a straight-line motion results. The outside of the curve is nearly a true circle, with a radius of 1 in. The pencil mechanism is carried by the cover of the outside cylinder, and consists of three pieces —the pencil-bar, the back-link, and the piston-rod link.

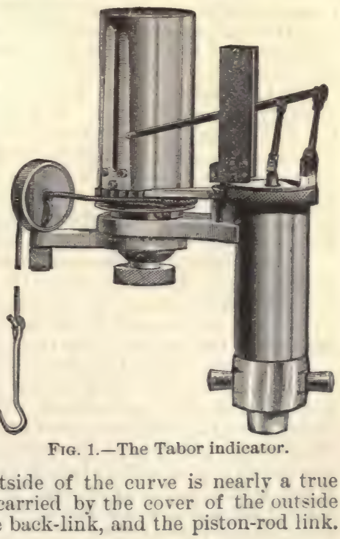


FIG. 1.—The Tabor indicator.

The two links are parallel with each other in every position they may assume. The lower pivots of these links and the pencil-point are always in the same straight line. If an imaginary link be supposed to connect the two in such a manner as to be parallel with the pencil-bar, the combination would form an exact pantograph. The slot and roller serve the purpose of this imaginary link. The springs are of the duplex type, being made of two spiral coils of wire. They are so mounted that the points of connection of the two coils lie on opposite sides of the fitting: this equalizes the side strain on the spring, and keeps the piston central in the cylinder.

The Crosby Indicator is shown in Fig. 2. The movement of the piston of the indicator is transmitted to the pencil by a simple parallel motion which gives it a movement in a straight line at right angles to the atmospheric line. The movement of the piston is multiplied to give a diagram of convenientsize, and at the same time to have the movement of the spring so slight that the pencil will immediately respond to any change of pressure in the cylinder. The spring is of unique and ingenious design, being made of a single piece of steel wire, wound from the middle into a double coil, the ends of which are screwed into a head D with four radial wings having spirally drilled holes to receive and hold them securely in place. Adjustment is made by screwing the spring in or out of the head until it is of the right strength, when it is securely fastened.

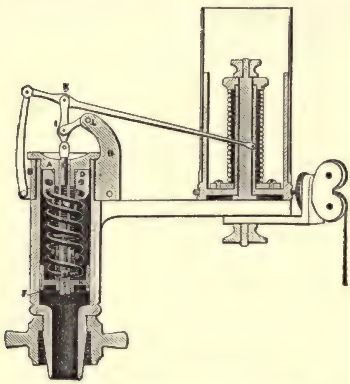


FIG. 2.—The Crosby indicator.

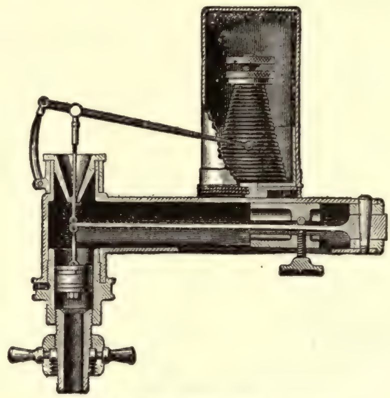


FIG. 3.—The Batchelder indicator.

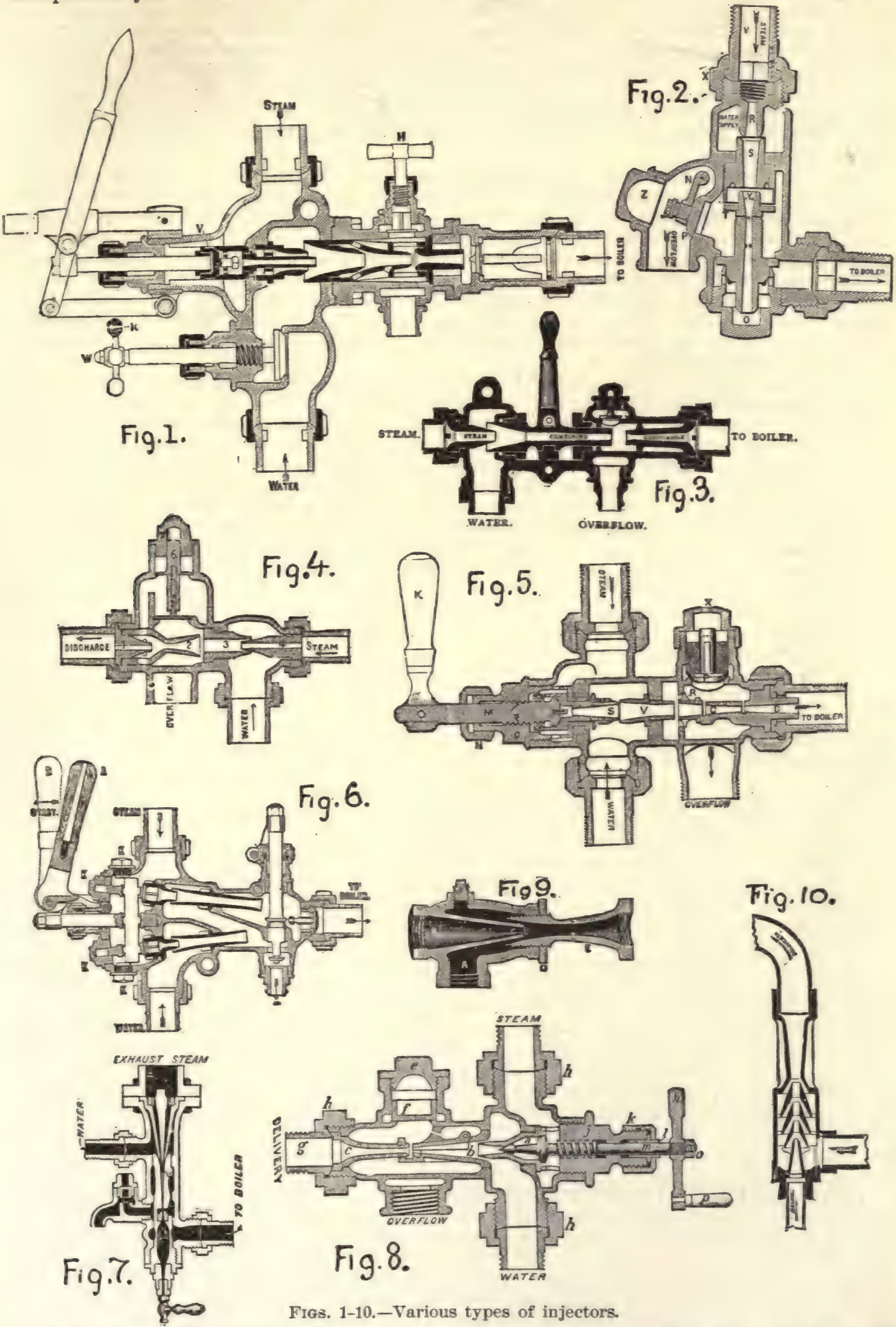
The Batchelder Adjustable Spring Indicator is shown in Fig. 3. The special features of this instrument consist in the T-shaped hollow case, adjustable flat spring, positive parallel motion, and stop-motion for paper drum. The cylinder is separate from the case proper. The flat steel spring works in the horizontal body of the case, one end being rigidly secured and the other attached to the connecting-rod between the piston and pencil-lever. The change of spring is made by removing the screw that connects it to the piston-rod, and the one which holds it in the case. Connection is made with the piston with a ball-and-socket joint. The scales are marked on the face of the case, the upper one being for low pressure and the other for high pressure. The parallel motion is secured by confining the end of the pencil-lever in a small roller which runs in the vertical slot. The height of the atmospheric line is adjustable by means of a swivel in the connecting-rod near the pencil-lever. The movement of the paper drum is controlled by the cone-shaped spring, which is adjustable to any tension according to speed.

INJECTORS. *The Monitor Injector* of 1888, made by the Nathan Mfg. Co., of New York, is shown in Fig. 1. It is adapted for use in locomotives, and may be used either with the lever attachment, as shown, or with a quick-motion, screw-starting arrangement. It has a range of capacity from 50 to 100 per cent of its maximum. It will lift the water 5 ft. with 30 lbs. steam-pressure. To operate it, the lever-valve, or the screw-valve in case the latter is used, is opened a short distance to lift the water till water runs from the overflow, when it is opened full. The quantity of water is regulated by the water-valve W. When used as a heater the valve H is closed, but at all other times it is kept open.

The Penberthy Automatic Injector, made by the Penberthy Injector Co., of Detroit, is shown in Fig. 2. Referring to the letters on the sectional view, the parts are as follows: V, tail-pipe; X, coupling-nut; R, steam-jet; S, suction-jet; T, ring; O, plug; N, overflow-hinge; P, overflow-valve; and Y, delivery-tube. The capacity of this injector may be cut down to one half of the maximum by throttling the water-supply valve.

The Little Giant Locomotive Injector of 1889, made by the Rue Mfg. Co., of Philadelphia, is shown in Fig. 3. It is used as a locomotive injector. The combining-tube is adjusted by a screw with fine graduations. The directions for operating are as follows: Have the combining-tube in position to allow sufficient water to condense the steam when the starting-valve is wide open; then open the starting-valve slightly; when water shows at the overflow, open the starting-valve wide, where it should remain while injector is at work. The quantity of water is graduated by moving the combining-tube. Toward the discharge gives more, and toward the steam gives less water. To use as a heater, close overflow by moving combining-tube against the discharge, and open steam-valve to admit what steam is required.

The Little Giant Stationary Injector is similar to the locomotive injector, but has no lever-starting valve. When used to raise water, a lifter is placed in the water-pipe with an independent jet.



FIGS. 1-10.—Various types of injectors.

The National Automatic Injector, made by the National Brass Mfg. Co., of Cleveland, is shown in Fig. 4. It will lift up to 20 ft., according to the surroundings, and will work equally well when taking water with a pressure. It does not need any adjustment from 20 to 125 lbs. steam-pressure, and it will take water heated to 130°. The parts numbered in the sectional view are the following: 1, delivery-tube; 2, combining-tube; 3, lifting-tube; 4, steam-jet; 5, immediate cut-off; 6, overflow-check; 7, overflow-cap.

The Metropolitan Automatic Injector, made by the Hayden & Derby Mfg. Co., of New York, is shown in Fig. 5. Referring to the letters on the cut, the parts are as follows: *S*, steam-jet; *V*, suction-jet; *C*, *D*, combining and delivery tube; *R*, ring or auxiliary check; *P*, overflow-valve; *O*, steam-plug; *M*, steam-valve and stem; *N*, packing-nut; *K*, steam-valve handle; and *X*, overflow-cap. It does not require any regulation of any valves in the suction-pipe for varying steam-pressure. It will start on 25 lbs. steam-pressure, and the steam-pressure can then be run up to 140 lbs. and back again to 25 lbs. without any adjustment of any globe-valves. At all steam-pressures from 25 lbs. to 140 lbs. it is absolutely automatic, and will always restart should either the steam or water supply be interrupted. It is either a lifting or non-lifting machine. It will lift 20 ft., and will always start, no matter how hot the suction-pipe becomes.

Korting's Universal Double-Tube Injector, made by L. Schutte & Co., of Philadelphia, is shown in Fig. 6. It is a combination of two steam-jet injectors, the first one proportioned for lifting and delivering the water under some pressure into the second, which forces it into the boiler. The quantity of water delivered by the first apparatus to the second is in proportion to the pressure of steam, so that the first acts as a governor for the second. The first has a proportionately small steam-nozzle to insure high suction, and, as it delivers water to the second under pressure, the latter can deliver the water to the boiler at a high temperature. During working hours the stop-valve on the boiler (which may be any kind of a valve) remains turned on, and the stopping and starting are solely effected by the lever *A* operating the valves in the steam-chamber of injector.

The Exhaust-Steam Injector, made by Schaeffer & Budenberg, is shown in Fig. 7. It is designed to utilize exhaust steam. It condenses, by means of the smallest possible quantity of cold water, the largest possible quantity of exhaust steam, and puts it into the boiler without the aid of any other power than the exhaust steam itself. It can be attached to any class of non-condensing engine. The water is delivered to the boiler at a temperature of about 190° F., against moderate pressure. Another form is designed to feed against a pressure up to 150 lbs. per sq. in. It is provided with an additional inlet by which live steam may be admitted with the exhaust steam. It is worked by waste steam only up to 75 lbs. pressure, and a little live steam is introduced at the top of the injector in order to force against pressures higher than 75 lbs. It will be noticed from sectional cut that the boiler-steam does not come in contact with the water until after the exhaust steam has been condensed and has done its work. The exhaust steam alone gives an impetus to the water equal to 75 lbs.; it also heats it up to about 190° F. It takes feed-water up to 90° F. if working against a pressure of 105 lbs., and up to 86° F. at 120 lbs. of pressure.

The Peerless Automatic Injector, made by Schaeffer & Budenberg, of New York, is shown in Fig. 8. It is adapted for any service requiring the lifting of water. It is generally made to lift from 16 to 18 ft., but can be arranged to lift 22 ft., and more if desired. It works under all pressures ranging from 30 to 150 lbs., and equally well whether lifting or non-lifting. The temperatures of feed-water taken by this injector, if non-lifting or at a low lift, can be as follows:

Pressure, lbs...	35 to 45,	50 to 85,	90,	105,	120,	135,	150.
Temperature..	144 to 136,	133 to 130,	129,	122,	118 to 113,	109 to 105,	104 to 100° F.

Referring to the letters in the sectional view, the parts are as follows: *a*, steam-nozzle; *b*, combining-nozzle with flap; *c*, delivery-tube; *e*, cap-screw for overflow; *f*, overflow-valve, *g*, tail-pipe; *h*, tail-pipe nut; *j*, screw-plug with stuffing-box; *k*, follower-nut on plug *j*; *l*, packing-sleeve to *j*; *m*, steam-spindle; *n*, crank to spindle *m*; *o*, screw-nut to spindle *m*; and *p*, handle to crank *n*.

McDaniel's Siphon or Water-Lifter is shown in Fig. 9. The lettered parts are as follows: *A*, suction-pipe; *B*, steam connection; *C*, end of cone or steam-delivery; *D*, jam-nut; and *E*, adjustable brass nozzle. It will lift water 20 ft. with ordinary steam-pressure.

Ejectors or Water-Lifters.—*The Nathan Mfg. Co.'s Ejector* is shown in Fig. 10. It is used as a means of raising liquids from one floor to another or conveying them from vessel to vessel, and in breweries, chemical works, and other places where the liquid is to be kept in a heated condition. It can also be employed to great advantage, instead of pumps, in distilleries, sugar-refineries, paper-mills, tanneries, print, dye, and other works, where liquids in different degrees of density are required to be raised or conveyed from place to place. It will take the liquid at a temperature of 175°. The steam enters at the left hand, as shown in the cut, and the suction-pipe is attached beneath.

IRON-MANUFACTURING PROCESSES. *Recent Developments.*—The manufacture of pig-iron has undergone no essential change during the last ten years, except in the improvement of the blast-furnace structure and its appendages, and in the method of management as respects increase of rate of driving. (On this subject see Furnace, Blast.) In the manufacture of wrought iron from pig-iron by puddling there has practically been no improvement. The various forms of mechanical puddling-furnaces described in vol. ii of this work have generally failed to meet expectations, and the old-fashioned puddling-furnace is still in vogue. Notwithstanding the rapid substitution of steel for iron for constructive purposes, the tremendous increase in the consumption of iron of all kinds has prevented the decline of the puddling process which was generally expected ten years ago, and the production of puddled iron in 1890 in the United States was greater than in any preceding year. (For the manufacture of steel, see Steel, Manufacture of.)

Direct Processes.—The several new direct processes described in vol. ii have all gone out

of use, never having practically progressed beyond the experimental stage. The old Catalan process still remains in existence, but is being generally abandoned in the United States; but a new plant is now being erected in Brazil, being copied, with some improvements, from an old plant in the Lake Champlain (N. Y.) region. Several new direct processes have been experimented with during the last few years, but it is at present too early to say whether they are likely to be permanent. Three of these processes—the Adams-Blair, the Carbon Iron Co.'s, and the Imperatori—are described below.

The Adams-Blair Direct Process is a new direct process which is now in the experimental stage in Pittsburgh. The apparatus used (Fig. 1) consists of an ordinary open-hearth steel

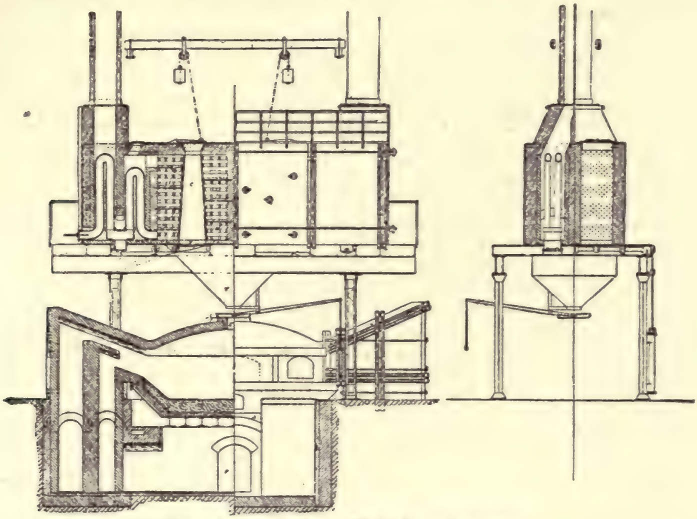


FIG. 1.—The Adams-Blair direct process.

furnace, on the top of which is placed the Adams reducer, which has vertical reducing-chambers flared downwardly from the top, with checker-work regenerative-chambers on each side of the reducing-chambers, and opening into them. This checker-work construction is provided with solid diaphragms, or baffling-walls, which prevent the upward passage of the gas through the checker-work, forcing it into the reducing-chamber and through the body of ore. The diaphragm on one side of the reducing-chamber is opposite the checker-work on the other. The ore is charged into these reducing-chambers, of which there are four, being retained in them by a movable valve. The reducing gas enters through the lower right-hand checker-work. As this checker-work offers less resistance to the passage of the gas than the column of ore does, the gas would pass directly up this checker-work instead of through the ore, were it not for the baffling-walls; these divert the column of gas, throw it into the reducing-chamber, and force it through the ore body and to the checker-work on the left-hand side of the chamber. In this checker-work the gas rises until it strikes the baffling-wall, where it is forced out again into the chamber and horizontally through it to the right-hand side, where the operation is repeated until the gas passes out through the upper checker-work. The reducing gas is thus brought in contact constantly and successively with all the ore in the reducing-chamber, absorbing the oxygen from the ore, leaving the iron in a metallic state, mixed with the earthy matter, ready to be fused into wrought iron or steel. In from an hour to an hour and a half the entire body of ore in one of these reducers (which are of any convenient size, according to the size of the open-hearth furnace which is to be supplied by them) is reduced completely, except where magnetites are used, in which case the operation is somewhat slower.

The Carbon Iron Co.'s Process.—A direct process is now in use at the works of the Carbon Iron Co., in Pittsburgh, which has given successful results in the production of iron blooms for remelting in the open-hearth furnace. The process has undergone some modifications since it was first described by A. E. Hunt, in a paper read before the American Institute of Mining Engineers (*Trans.*, vols. xvi, p. 708, and xvii, p. 678). Prof. G. W. Maynard thus describes it as at present operated, in the *Trans.*, vol. xix, p. 850:

"As at present practiced, it consists in charging an intimate mixture of wet, finely ground iron-ore and coke upon the cinder hearth of an ordinary reverberatory or puddling furnace, and heating the charge with natural gas in an atmosphere that is moderately oxidizing. The ore is reduced by its intimate contact with the ground coke, and the iron is balled at nearly a white heat. Two points require special mention: First, the benefit of mixing the ore and coke very intimately, as by such mixture it is found that the fine particles of ore protect the carbon particles from too rapid combustion, and time is secured for the thorough reduction of the iron oxide. Second, the importance of using none but the richest ores, or cleanest concentrates, as it is only by such practice that the loss of metal can be kept down to a com-

mercially practicable limit. Sixty-five per cent Lake Superior ores, carrying 3 or at most 4 per cent of silica, furnish the present supply. One long ton of this ore is mixed with 600 lbs. of ground coke, and yields at the present time 1,325 to 1,375 lbs. of squeezed sponge, which runs nearly 93 per cent of total iron. The quantity of natural gas consumed per ton-of product has not yet been ascertained, but it is roughly estimated at the amount required to puddle a ton of pig-iron in a non-regenerative furnace of the same type as the reducing-furnace—that is, about 35,000 cub. ft. of natural gas, or 2,700 lbs. of Pittsburgh coal."

The Imperatori Process is a sort of mixed process in which a large amount of rich ore can be treated in presence of a metallic bath. It consists substantially in treating an intimate mixture of finely pulverized rich iron-ore (at least 50 per cent of iron) and carbonaceous materials, agglomerated into briquettes, in the presence of a metallic bath of pig-iron or carbureted iron. The relative proportions of carbon and ore are calculated in such a manner that the carbon is present in sufficient quantities to reduce the ore directly to the metallic state, without previously being transformed into a carbureted product. A record of experiments on this process, made by Mr. J. B. Nau, will be found in *Trans. Am. Inst. of Min. Eng'rs*, June, 1891.

Manufacture of Russia Sheet-Iron.—Mr. F. Lynwood Garrison describes the manufacture of planished sheet-iron in Russia as follows (*Jour. Charcoal Iron-Workers' Asso'n*, vol. viii):

The ore, containing about 60 per cent iron, 5 per cent silica, 0·15 to 0·06 per cent phosphorus, is generally smelted into charcoal pig-iron and then converted into malleable iron by puddling or by a Franche-Comté hearth. Frequently, however, the malleable iron is made directly from the ore in various kinds of bloomaries.

The blooms or billets thus obtained are rolled into bars 6 in. wide, ¼ in. thick, and 30 in. in length. These bars are assorted, the inferior ones piled and rerolled, while the others are carefully heated to redness and cross-rolled into sheets about 30 in. square, requiring from 8 to 10 passes through the rolls. These sheets are twice again heated to redness and rolled in sets of three each, care being taken that every sheet before being passed through the rolls is brushed off with a wet broom made of fir, and at the same time that powdered charcoal is dexterously sprinkled between the sheets. Ten passes are thus made, and the resulting sheets trimmed to a standard size of 25 × 56 in. After being assorted and the defective ones thrown out, each sheet is wetted with water, dusted with charcoal-powder, and dried. They are then made into packets containing from 60 to 100, and bound up with the waste sheets.

The packets are placed, one at a time, with a log of wood at each of the four sides, in a nearly air-tight chamber, and carefully annealed for 5 or 6 hours. When this has been com-

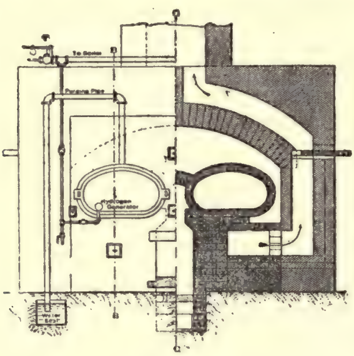


Fig. 2.

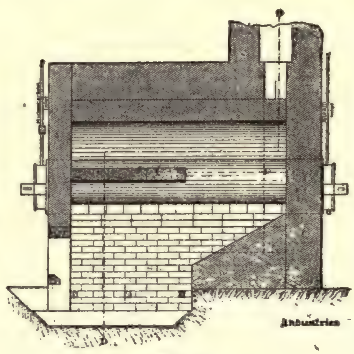


Fig. 3.

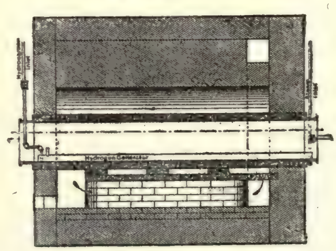


Fig. 4.

Figs. 2-4.—The Gesner rust-proof process.

pleted, the packet is removed and hammered with a trip-hammer weighing about a ton, the area of its striking surface being about 6 × 14 in. The face of the hammer is made of this somewhat unusual shape in order to secure a wavy appearance on the surface of the packet. After the packet has received 90 blows, equally distributed over its surface, it is reheated, and the hammering repeated in the same manner. Some time after the first hammering, the packet is broken and the sheets wetted with a mop to harden the surface. After the second hammering the packet is broken, the sheets examined to ascertain if any are welded together, and completely finished cold sheets are placed alternately between those of the packet, thus making a large packet of from 140 to 200 sheets. It is supposed that the interposition of these cold sheets produces the peculiar greenish color that the finished sheets possess on cooling.

This large packet is then given what is known as the finishing or polishing hammering.

For this purpose the trip-hammer used has a smaller face than the others, having an area of about 17 to 21 in. When the hammering has been properly done, the packet has received 60 blows, equally distributed, and the sheets should have a perfectly smooth, mirror-like surface. The packet is now broken before cooling, each sheet cleaned with a wet fir broom to remove the remaining charcoal-powder, carefully inspected, and the good sheets stood on their edges in vertical racks to cool.

American Polished Sheet-Steel.—Sheet-iron and steel similar in quality and in process of manufacture to that of the Russia sheet is now made in the United States, and is known by various trade names, as planished iron, Craig polished sheet-steel, etc. The latter is made in sheets 28 × 60 in., and from 22 to 28 gauge. The sheets are coated with carbonaceous materials, and are then heated and hammered in packs, while hot, under powerful steam-hammers.

The Gesner Rust-Proof Process employs apparatus shown in Figs. 2, 3, and 4. This consists of a bench of two ordinary gas retorts placed side by side in a furnace heated by a grate. Each retort is heated to a temperature of 1,000° F. to 1,200° F., as may be determined by the character of the articles to be treated. After closing and testing the retort, the heating continues for about 20 min.; then steam is introduced into a "hydrogen generator," shown in Figs. 3 and 4, which is a simple pipe, open at the rear end. It is claimed that in the passage of the steam through this generator hydrogen is generated, which fills the retort. This operation goes on for 35 min., at the end of which time half a pint of naphtha is permitted to flow into the retort for 10 min. The flow of hydrocarbon is then stopped, and the steam which has been allowed to enter the generator during the whole operation is continued for 15 min. longer. The whole time employed in the operation is therefore 1 hour and 20 min. The "purging-pipe," which dips into an open vessel of water, as shown in Fig. 2, to the depth of 1½ in., carries off any excess of gases produced in the operation. In cases where articles treated are ornamental, such as art hardware, they are given a bath of cold whale-oil or paraffine oil to render them more even in tone. To substantiate the claim that hydrogen has a function in the creation of a rust-proof coating, the following analysis of a sample of the surface of cast iron prepared by the process is given: Carbon, 1·01 per cent; hydrogen, 0·22 per cent; sand, 6·70 per cent; and iron, 66·10 per cent. The iron is present as metallic iron and as oxides of various constitution.

Jacket, Steam: see Engines, Steam Stationary Reciprocating; also Locomotives.

Jack-Lifting: see Drills, Rock.

Jenny: see Rope-Making Machines.

Jig: see Coal-Breakers and Ore-Dressing Machines.

Jig-Saw: see Saws, Wood.

KEYS. *Machine-made Keys.*—Fig. 1 represents the shape of machine keys made by the Sandwich Manufacturing Co., of Sandwich, Ill., in the following manner: Each machine consists of three co-acting, revolving steel hammers, the upper and principal set acting on and drawing out the heated rod to its required taper, and the side-sets acting on the edge and forging the sides to true lines. Adjustable gauges regulate the length and taper, self-acting shears with gauge cut off the forged end of the rod to the exact length required, after the quick thrust to the forging rollers or hammers, and self-acting straightening jaws seize and straighten each key as it drops from the shears, and then drop it into a cooling-hopper. In the operation of forging, each operator has six or eight bars or rods of the required size for the job in hand, in his slow fire. Drawing one from the fire and turning to his machine he thrusts it between the hammers against the gauge, which determines the length of the key, and in the moment while retiring it the action of the hammers forges it perfectly to the required taper and form. It is then presented to the shears, and the formed key is cut from the rod. He usually forges and cuts about three keys and returns it to the fire for a new heat, takes a fresh rod and repeats the operation, and so on through the six or eight, by which time the first one returned is sufficiently heated. The usual sizes, made for stock, are $\frac{1}{4}$, $\frac{5}{16}$, and $\frac{3}{8}$ in. wide, by from $\frac{1}{8}$ to $\frac{3}{16}$ in. thick and from 2½ to 4 in. long.

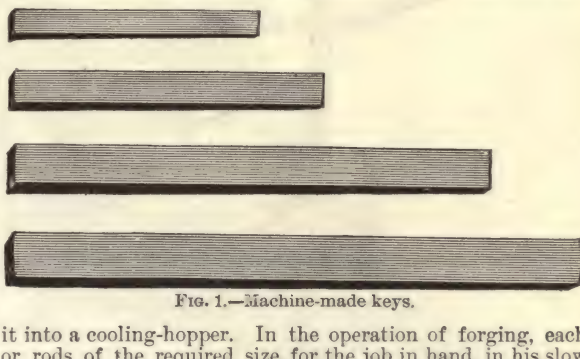


FIG. 1.—Machine-made keys.

The Woodruff System of Keying.—The Woodruff Manufacturing Co., of Hartford, Conn., has brought out a novel system of keying, which is illustrated in the accompanying cuts. Under this system the key-seat is cut longitudinally in the shaft, as shown in Fig. 2, by means of a milling-cutter (Fig. 3). This cutter corresponds in thickness to the key to be inserted, and is of a diameter corresponding to the length of the key. The key being a semicircle, the cutter (Fig. 3) is sunk into the shaft as far as will allow sufficient projection of the key above its surface to engage the key-

FIG. 2.—Woodruff cut.

way in the hub it is designed to hold in position. The operation of cutting the key-seat is simple, and does not require skilled labor. Where a long key or feather is required, two or more keys are inserted, in the manner shown in Fig. 2. Owing to its peculiar shape, the key may be slightly inclined, so that it will serve to support the pulley on a vertical shaft, provided the key-seat in the hub of the pulley is made tapering and of the proper depth. There are twenty-five different sizes of keys used in the system, the standard scale of sizes being such as to meet the requirements of a large majority of the machines now made.

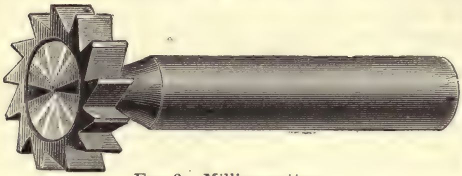


FIG. 3.—Milling-cutter.

The accompanying table gives the size and strength of these standard sizes.

SIZE OF KEYS AND CUTTERS CORRESPOND.			Shearing strength of keys in pounds.
No.	Length.	Thickness.	
1	$\frac{1}{2}$	$\frac{1}{16}$	1.566
2	$\frac{1}{2}$	$\frac{3}{32}$	2,350
3	$\frac{1}{2}$	$\frac{1}{8}$	3,132
4	$\frac{5}{8}$	$\frac{3}{32}$	2,937
5	$\frac{5}{8}$	$\frac{1}{8}$	3,915
6	$\frac{5}{8}$	$\frac{5}{32}$	4,894
7	$\frac{3}{4}$	$\frac{1}{8}$	4,700
8	$\frac{3}{4}$	$\frac{5}{32}$	5,872
9	$\frac{3}{4}$	$\frac{3}{16}$	7,050
10	$\frac{7}{8}$	$\frac{5}{32}$	6,850
11	$\frac{7}{8}$	$\frac{3}{16}$	8,221
12	$\frac{7}{8}$	$\frac{7}{32}$	9,591
13	1	$\frac{3}{16}$	9,375
14	1	$\frac{7}{32}$	10,937
15	1	$\frac{1}{4}$	12,500
16	$1\frac{1}{8}$	$\frac{3}{16}$	10,545
17	$1\frac{1}{8}$	$\frac{7}{32}$	12.305
18	$1\frac{1}{8}$	$\frac{1}{4}$	14,062
19	$1\frac{1}{4}$	$\frac{3}{16}$	11,718
20	$1\frac{1}{4}$	$\frac{7}{32}$	13,671
21	$1\frac{1}{4}$	$\frac{1}{4}$	15,625
22	$1\frac{3}{8}$	$\frac{1}{4}$	17,187
23	$1\frac{3}{8}$	$\frac{5}{16}$	21,484
24	$1\frac{1}{2}$	$\frac{1}{4}$	18,750
25	$1\frac{1}{2}$	$\frac{5}{16}$	23,437

Key-Seat Milling-Machine: see Milling-Machines.

KEY-SEAT CUTTERS. *The Morton Key-Way Cutter* made by the Morton Manufacturing Co., of Muskegon, Mich., is shown in Fig. 1. One of the main features of this machine is the oscillating guide for cross-head, which oscillates from the center line of the main shaft, giving the tool a straight-drawing cut. By means of the adjusting-screw to the left, on front of table, the tool can be inclined forward or backward from a vertical position, whereby the machine may be set to cut a key-way, tapering either from the top or bottom, with the same side down. The stroke of the machine is adjusted, as is the stroke of a planer, by adjustable tappets. The guide for work consists of a plate which fits in a groove at the top of the table, and has a projection on each side of the tool-bar which forms a guide to set work to, gauging by bore of pinion.

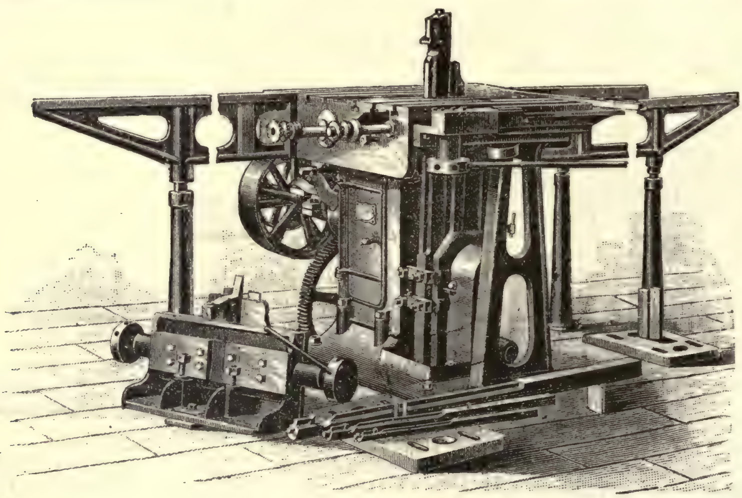


FIG. 1.—Morton key-way cutter.

The machine is made in different sizes, the one shown in the cut being known as the No. 6—24 machine. Its capacity ranges from the smallest key-ways to be cut up to one $2\frac{1}{2}$ in. wide and 24 in. long.

The Davis Key-Seater and Slotting-Machine is shown in Fig. 2. The frame is made of one casting, together with the ways. In the machine shown in Fig. 2, the gears are $1\frac{5}{8}$-in. face, and are all cut gears. The connection-rod is so arranged as to keep chips and dirt from falling into the crank-pin. The ways are bored out and the top of frame faced. The stud-pins to the clamp are provided with washers, and so arranged that the clamp can be placed between them at any height required, and will not drop down. A simple arrangement is also furnished to give any desired draft to key-seat required, also any depth. This machine will cut $\frac{1}{4}$-in. to 1-in. key-seats.

The Erie Key-Seating Machine, made by the Burton Machine Co., of Erie, Pa., is shown in Fig. 3. The arbor is hollow, and has within it a steel bar called the guide-bar, and is movable up and down by means of a screw at each end. It carries within it a tool-bar, which supports two tools of the width desired for the key-seat, and is connected to the driving-car-

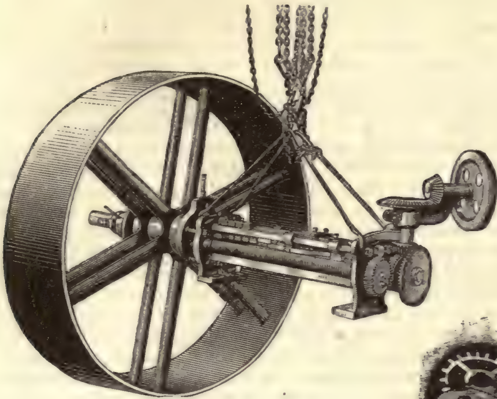


Fig. 3.—Erie key-seating machine.

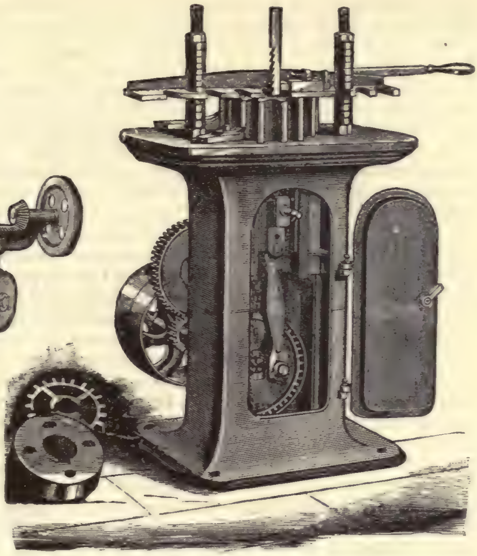


Fig. 2.—Davis key-seater.

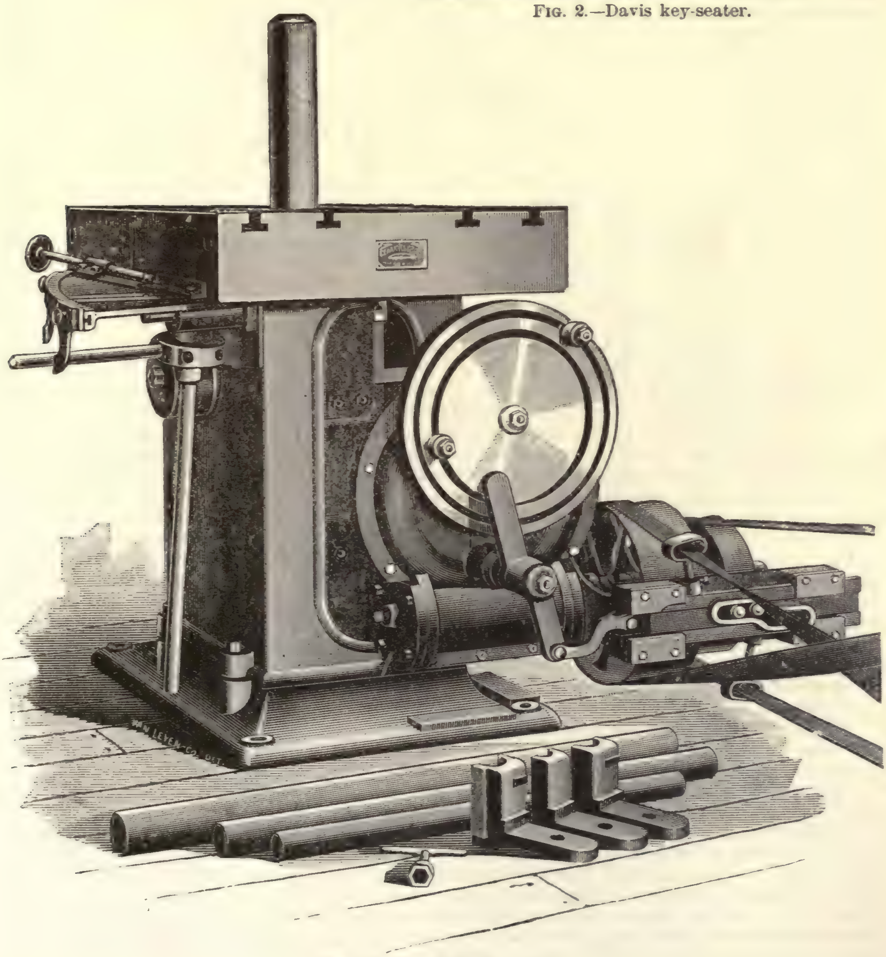


Fig. 4.—Giant key-seater.

riage by means of a removable pin. It is driven back and forth through the guide-bar, cutting in both directions, and fed down the desired depth and taper by the screws at the ends. The driving apparatus consists of two parallel screws, 2½ in. in diameter, 1½-in. pitch, 3 threads. They are set 6 in. from center to center, and run in opposite directions; between them is an open-sided nut, which carries with it a carriage to which the cutting-bar is attached.

The Giant Key-Seater, made by the Giant Key-Seater Co., of Saginaw, Mich., is shown in Fig. 4. The machine consists of an upright column, supporting on trunnions a table in which are T-slots for securing the work to be operated upon. Inside the column is a vertical guide, on which slides the cross-head, having on its face a V-groove, for centering the round tool-bar, which is clamped. The cross-head receives its motion through a rack, which meshes in a spur-gear of wider face than the rack. The gear is keyed on a horizontal shaft, to which is also keyed the worm-gear inside of gear-casing, the shaft extending through the casing, and having secured to it a disk, which has two circular T-slots turned in its face, in each of which is a tappet which reverse the motion by shifting the open and crossed belts running from the counter-shaft, as shown. The tappet, which acts at the end of the slow or cutting stroke, is placed in the outer of the two circular T-slots in the disk. By moving the tappets in the slots, the stroke of the cutter can be varied as desired, without stopping the machine. To provide for forward movement of cutter in the work, the vertical guide is arranged to slide in ways at the top and bottom, being moved forward and back by wedges, which are operated by the feed-lever shown at the left of the machine. As the cutter, cutter-bar, and guide are advanced, the rack on cross-head slides in the cogs of the spur-gear with which it meshes; the pinion having a wider face than the rack, as stated above.

Kiln: see Brick-Making Machines; also, Furnaces, Roasting.

KILNS, LUMBER. In these days of rapid conversion of material, and of short periods between the various processes of conversion, little could be done by the converter of wood without the aid of efficient lumber-drying kilns, taking the place of the old-fashioned long-seasoning process in air or water.

An automatic hot-blast apparatus, put out by the Standard Dry Kiln Co., consists of a high-speed blowing-fan, directly driven by an inverted vertical high-speed engine, and connected with a case or chamber in which there are arranged a series of vertical spiral coils of pipe, through and about which the air enters before being removed by the fan. Into one of the series of pipes (that farthest from the engine and nearest to the entrance of the air to be heated) the exhaust of the engine is led, thus receiving the greatest amount of condensation that could be obtained by such an arrangement, and lessening the back-pressure upon the engine. Some of the rest of the coils in the duct or chamber receive live steam, if desired, but the connections are such that as many as desired receive the exhaust from the main or steam-engine. A steam-jet regulates the degree of humidity of the air. A steam-trap, through which the water of condensation drains when live steam is being used, automatically regulates the amount consumed.

A hot-air duct used in this device has a regulator for controlling the delivery of air to each opening in the duct, preventing the air from rushing by the openings nearest the blower. A series of semi-cylindrical slides drop from the cross-outlets into the body of the main duct, thus retarding the air and forcing it out through the cross-ducts into the kiln. The cross-duct nearest the heater ordinarily has its slide projecting farthest into the main duct, although, if desired, any one section of the kiln may be given an increased proportion of air.

In the Standard kiln the lumber is loaded upon cars at what is called the "green end," and run into the kiln on iron tracks at the rate of two or more cars per day, in each of the rooms composing the kiln. Each car holds about 4,000 ft. of lumber, and each room will contain 12 cars; so that the lumber while in transit remains in the drying process from 3 to 6 days, depending upon the class of stock, before it is run out at the "dry end" of the kiln. The temperature at the end of the kiln in which the heated air centers, and at which point the process of seasoning is completed, is about 185° F., corresponding to an absorbing capacity of 194 gr. per cub. ft. of air. At that end at which the lumber enters, where the temperature is 125° F., the absorbing capacity is only about 30 gr., so that the action is gradually increasing —being in this particular much easier upon the stock, drying it more thoroughly and greatly lessening checking.

Knotter: see Harvesting-Machines, Grain.

Knox System of Blasting: see Quarrying-Machines.

Knurling-Tool: see Lathe-Tools, Metal-Working.

Ladders, Fire: see Fire Appliances.

Land Roller: see Seeders and Drills.

Lapping-Machine: see Grinding-Machine.

Lasting-Machine: see Leather-Working Machines.

Lathe: see Hat-Making Machines, Watches and Clocks, Wheel-Making Machines, Mowers and Reapers.

LATHES, METAL-WORKING. *The Putnam Engine-Lathe.*—Figs. 1 to 6 illustrate a new standard lathe recently brought out by the Putnam Machine Co., of Fitchburg, Mass. Figs. 1 and 2 represent the bed in longitudinal and cross-section. This is a heavy U-shaped casting, strengthened by a strong truss extending from end to end. This truss is stiffened by a bead at the top, and is connected by lateral webs to the sides of the bed. Ribs placed at suitable distances apart extend from the under side of the top down the sides, firmly uniting the members of the bed. The front carriage A is made higher and larger than the back A.

The construction of the head-stock is shown in Fig. 3. The boxes are conical-shaped on the outside, straight on the inside, and fitted to correspondingly tapered holes, or seats, in the

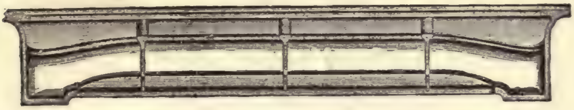


FIG. 1.—Bed—section.

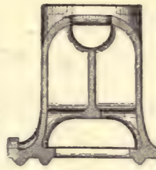


FIG. 2.—Bed—cross-section.

metal of the head-stock casting. They are split for adjustment, and are threaded at their ends for the adjusting-nuts *N N*. The nut *N* has a spherically shaped projection, and in addition to serving as an adjusting-nut for the back spindle-box, is threaded from the step *S*, which through a rawhide collar takes the thrust of the spindle. *O* is a lock-nut to secure the step against turning after it is properly adjusted. A steel collar is fitted with a feather to slide on the spindle, and is held in position by nuts. This, being adjusted to contact with the end of the box, holds the spindle from end-long motion in one direction, while it is held from motion in the other direction by the step *S*. This construction is intended to prevent disturbance of adjustment due to contraction and expansion from changes of temperature. When adjusted, the boxes are restrained from turning in their seats by the adjusting-nuts, which are always screwed against the casting; but while being adjusted to the spindle, pins in the outside of the boxes fit in grooves in the seats, these grooves holding the boxes from turning around, but permitting lateral movement. A series of holes is drilled around the circumference of the boxes, so that by placing the pins in different holes the boxes may be occasionally partially rotated in their seats, thus equalizing the wear, and tending to keep the spindle in a central position.

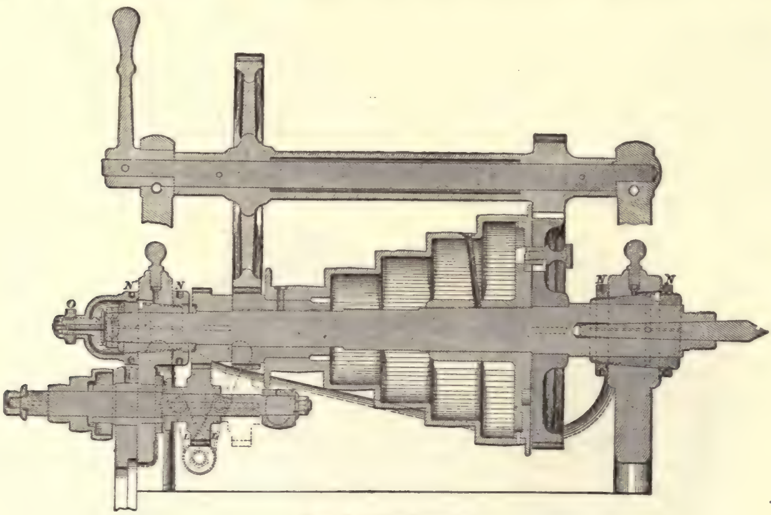


FIG. 3.—Head-stock.

The handle *L* (Fig. 3) is for disengaging or changing from coarse to fine or fine to coarse feed, which is done by means of the following arrangement: The feed-gear inside the head is on a feathered shaft, and may, by moving the handle to the two positions shown by dotted lines, be geared to either the gear on the spindle or that on the cone, the difference in feed between the two positions being 9 to 1. This, which is applicable to either longitudinal or cross feed, or to screw-cutting, with the changes of both gear and belt-feed to the feed-rod, provides for a great range of feed, from that fine enough for any purpose to that extremely coarse, for surface-work or for cutting screws or worms of coarse pitch.

Fig. 4 is a section through the carriage and bed. The feed-rod is at the front and the lead-screw at the back side. To lock the nut and lead-screw, a rod extends across the carriage (on all lathes above 18 in. swing) from the front to the rear, where, by means of the pinion *H*, it connects with the plate *I*. The operation of bringing together or separating the half-nuts of the lead-screw is accomplished by turning the rod. The rack-gear and pinion-shaft is, by means of the yoke *K*, provided with a second bearing, the working strain coming between the two journals. To avoid the possibility of locking the nut to the lead-screw while the gear and rack are connected, or *vice versa*, a safety-pin is connected with the yoke *K*, and the hub of the lever that operates the lead-screw nuts has in it a hole to which this pin

is fitted. This hole is in such a position that when the rod is turned to bring the nuts together on the screw it will not be in alignment with the pin. If, now, an attempt is made to raise

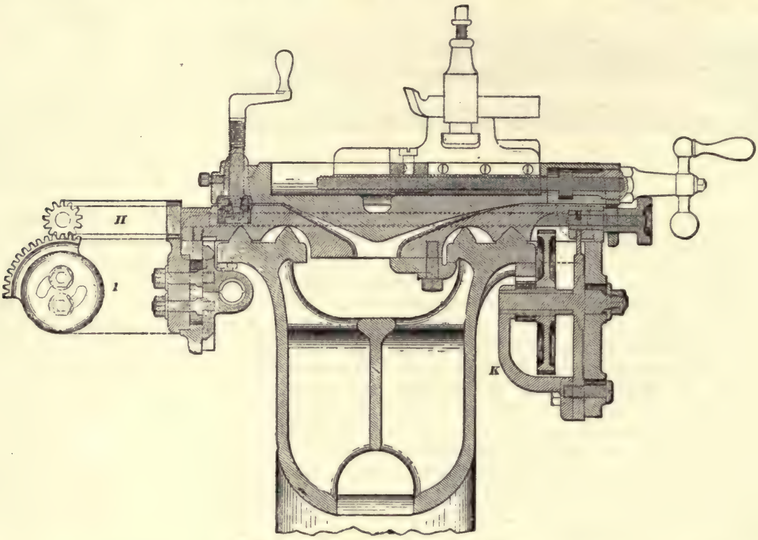


FIG. 4.—Carriage and feed-table.

the yoke so that the pinion will gear with the rack, the pin will come in contact with the plain surface of the hub, preventing its accomplishment. When the disk is turned to the position in which it stands when the nut is off the screw, the hole is in alignment with the pin, and the yoke may be raised to gear the rack and pinion together. If, when the rack and pinion are in gear, an attempt is made to connect the nut with the lead-screw, the pin will prevent the disk (and rod) from turning. This makes it impossible to do damage by the attempted operation of both screw and rod-feed at the same time.

In Fig. 5 the tail-stock is shown in two sections. It has a long bearing on the ways, and an extension that serves for a tool-shelf. The front bearing is split for binding the spindle.

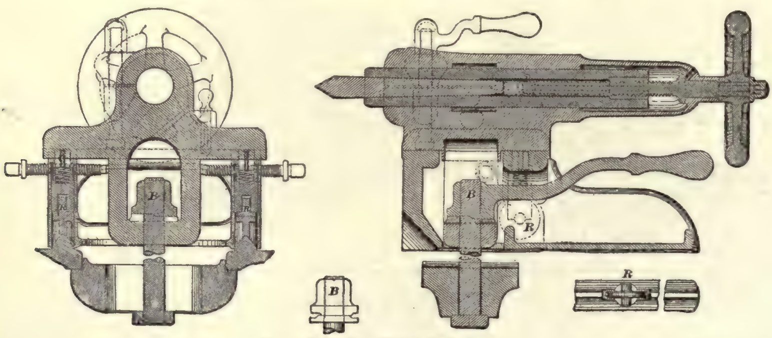


FIG. 5. - Tail-stock.

To overcome the difficulty of moving it against the sliding-friction of the ways, wheels *R* are placed as shown, one at each side over the ʌ's. These wheels are so mounted as to be free to move vertically a short distance, and are loaded by adjustable springs. When the tail-stock is loosened the springs tend to assume the load, thus transferring the weight to the wheels, and transposing the hard sliding to an easy rolling motion. The arrangement for clamping the tail-stock to the ways is shown at *B*. It consists of a binding-bolt and nut, the face of the nut being cam-shaped, to correspond with the cam-shaped washer underneath it. In tightening, the somewhat abrupt faces of the cams take up the slack motion by a slight movement of the handle, when the nut and thread bind the tail-stock rigidly. Similarly, in loosening the tail-stock the abrupt angle of the cams gives the necessary freedom with the same small amount of motion. The back-rest has a lever-handle lock-nut.

Fig. 6 is a perspective view of a 14-in. swing-lathe of this type.

Car-Wheel Lathe.—Fig. 7 illustrates a car-wheel lathe built by the Niles Tool Works, of Hamilton, O., especially designed for turning steel-tired car and truck wheels on their axles. The problem presented in this case is to grip the axles by their journals, keep them in line

with each other, and revolve them about their common centers, whether these should be true with the original centers of the axle or not. This is accomplished in the following manner:

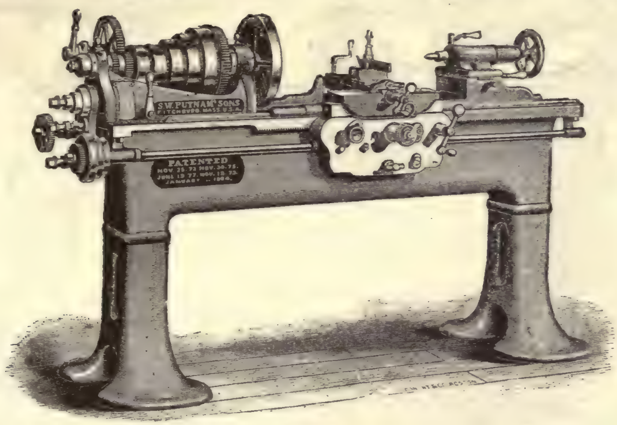


Fig. 6.
Figs. 1-6.—Putnam engine lathe and details.

The lathe is arranged with two face-plates revolving on hubs projecting from each head turned true and placed in exact alignment. Within these face-plates and revolving with them are placed two very strong, self-centering chucks, with four swivel jaws. They are operated by gearing mounted on each head-block. These grip the axle firmly about the centers of the journals, and with the face-plates revolve them in exact line. The two face-plates are geared together in the same manner as on driving-wheel lathes, by a heavy forged steel shaft. The chucks above mentioned are used only to center the work and insure the wheels being turned true with the journals. The wheels are revolved by two drivers on each face-plate, which engage with the heads of the bolts used to secure the tire to the wheel-center. These drivers are adjustable both lengthwise and radially to suit any wheel. Each head is arranged with a sliding spindle, with centers, which are capped to prevent end-motion of the axle when used for turning truck-wheels with inside journals. These caps can be removed and the spindles run out beyond the face-plates, when the work may be carried on the centers. The right-hand head is movable on the bed by rack and pinion. As the chucks

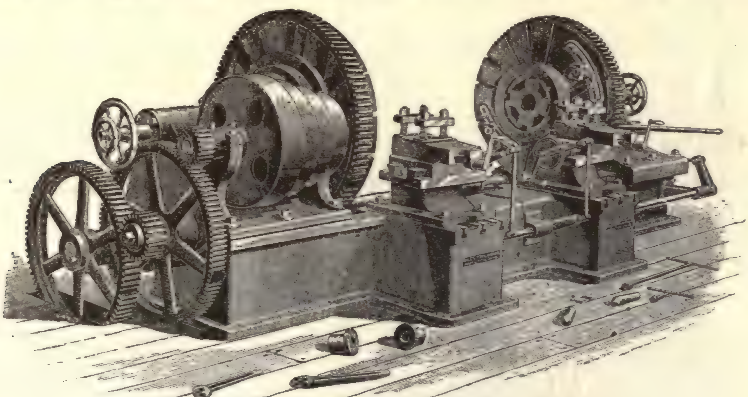


Fig. 7.—The Niles car-wheel lathe.

have swivel-jaws, they will accommodate themselves to the work as it is put into the lathe. The feeds are operated from the driving-shaft by means of a rock-shaft placed in front of the machine, and work through the means of a racthet-lever in the same manner as on driving-wheel lathes.

Forming-Lathe.—Fig. 8 shows a forming-lathe made by the Meriden Machine-Tool Co., Meriden, Conn. This machine is designed for turning large numbers of pieces to certain shapes, such as handles, cocks, packing-nuts, glands, bonnets, caps, nipples, etc. The turning is done by a single motion of one lever. The first part of the motion of the lever tightens the chuck, and a further movement brings the forming tool forward under the work and turns it to shape, after which the tool drops sufficiently to clear the work during the reverse motion of the lever, which motion loosens the chuck and raises the tool at the proper time and in position for another cut. All operations are performed without stopping the lathe.

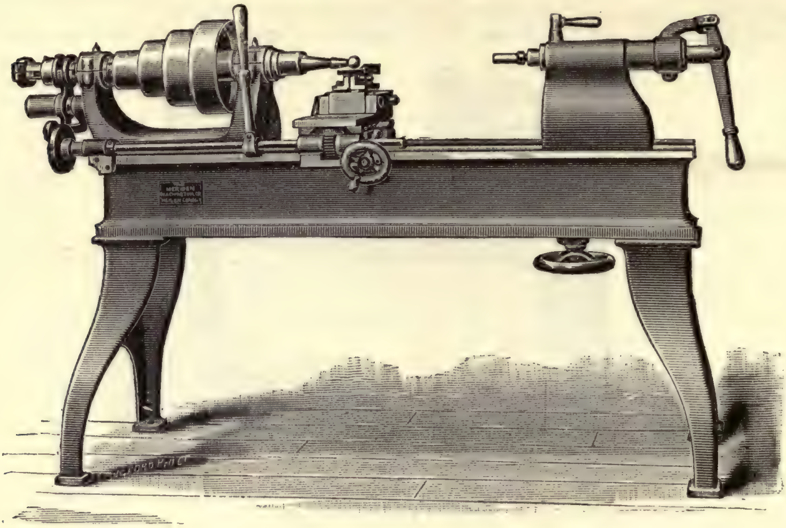


FIG. 8.—The Meridan forming-lathe.

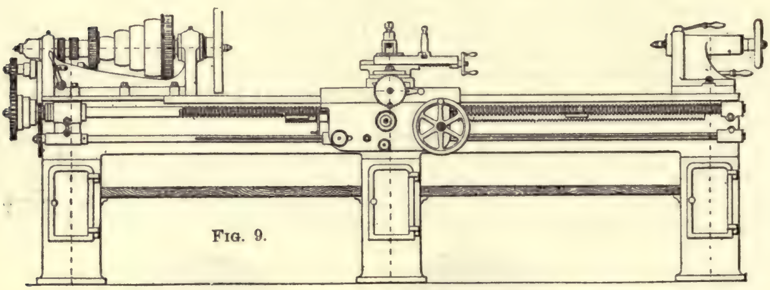


FIG. 9.

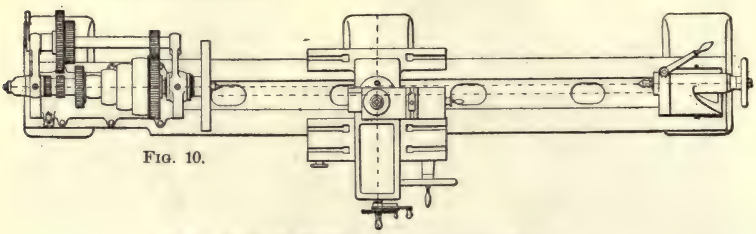


FIG. 10.

FIGS. 9, 10.—Richards' Anglo-American lathe.

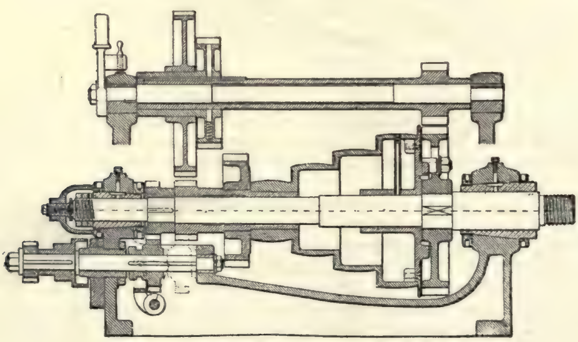


FIG. 11.—Richards' lathe—head-stock.

Richards' Anglo-American Lathe.—Figs. 9 to 11 illustrate a lathe made by George Richards & Co., Limited, of Broadheath, near Manchester, England, and exhibited by them at the Paris Exhibition of 1889. It is called an Anglo-American lathe, and is intended to combine the best features of American and English practices. Figs. 9 and 10 show the machine in elevation and plan, while Fig. 11 is a detail section of the fast head-stock. This, it will be seen, has an arrangement of back-gearing giving an extra set of speeds by equal pinions on the spindle and back-shaft. The spindle has parallel necks, hardened and ground true, in which run taper bushes as shown, and wear can thus be compensated for. The thrust is taken up at the back end of the spindle, which is surrounded by a metal cap intended to be filled with oil, and thus the thrust-bearing is efficiently lubricated. The feed is taken from the spindle by the sliding-pinion shown below it, and the rate of feed can be changed by causing this pinion to gear either with that on the spindle or that on the cone. The tool-carriage is moved by a rack and pinion in ordinary work, and by a screw in screw-cutting. All the feed-motions of the carriage can be reversed. The guiding surfaces, both back and front, are square. The sliding head-stock is arranged to set over slightly, and thus allow long tapers to be turned.

Gap Chucking-Lathe.—Fig. 12 shows a gap chucking-lathe made by the Putnam Machine Co. It is an improved tool of great range and capacity, with 25 and 50 in. swing, the gap

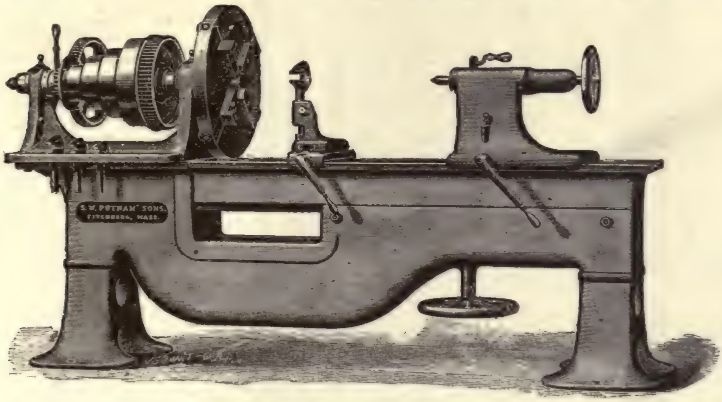


Fig. 12.—Gap chucking-lathe.

being $20\frac{3}{4}$ in. long. The cone is balanced, and has four shifts for a wide belt. The head-stock has ground journals with anti-friction metal boxes, which compensate for wear and preserve the original alignment of the live and dead centers. The bed-slider is operated by rack and pinion.

Pulley-Lathe.—Fig. 13 shows a lathe built by the Niles Tool Works, of Hamilton, Ohio, especially designed for turning pulleys, gears (both spur, beveled, and mortised), small fly-wheels,

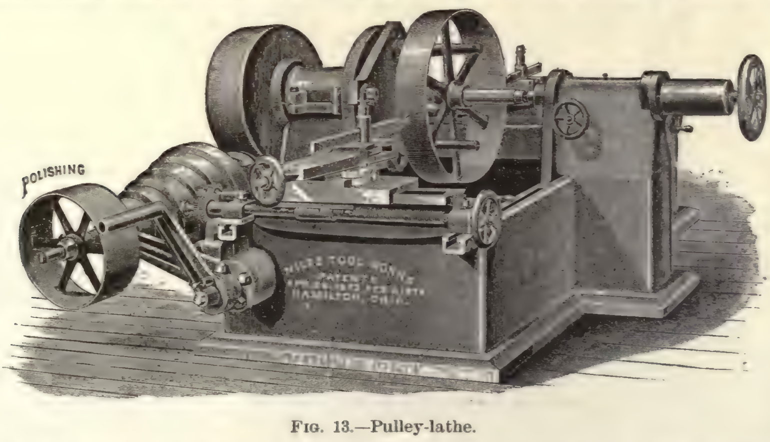


Fig. 13.—Pulley-lathe.

and work of a similar character. Power is transmitted to the spindle through tangent gearing. The pulleys, being first bored, are placed on a mandrel and are driven by an equalizing driver, distributing the strain evenly on the arms. The tool-slides are mounted upon short, stiff cross-rails, which are adjustable on graduated surfaces of the bed to suit the diameter of pulley to be turned. The rails may be set over at an angle to give any desired degree of

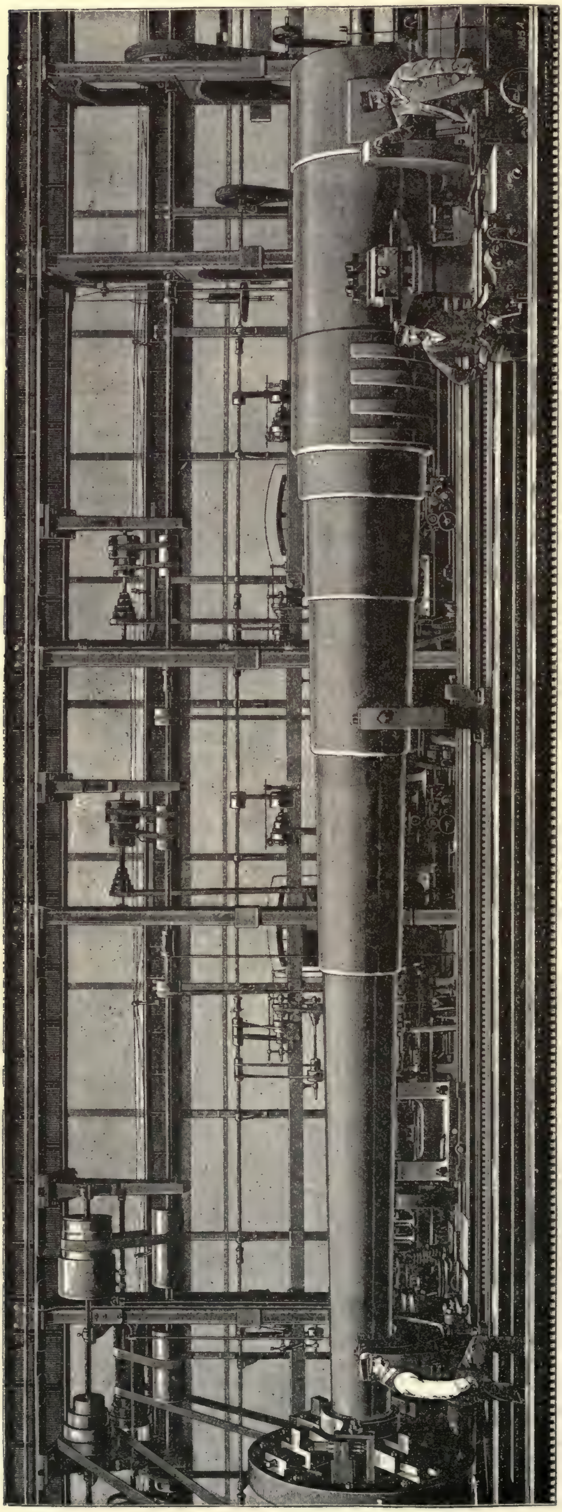


Fig. 14.—Gun-lathe of the Forges et Chantiers, Havre.

"crown." Tools are thus operated on both sides of the machines. Feeds are operated from the end of the driving-shaft by three-step cones for $1\frac{1}{2}$-in. belt, communicating power to the feed-shaft by means of gears with an in-and-out pin. This arrangement gives a roughing and finishing feed for each adjustment of feed-belt. The front rest has compound movement and power cross and angle feed. The driving shaft runs at so much higher velocity than the main spindle that its speed is suitable for polishing while the lathe is turning.

Gun-Lathe of the Forges et Chantiers, Havre.—Fig. 14 shows a gun-lathe in the factory of the Forges et Chantiers, Havre, France, with a 66-ton gun, built for the Japanese Government, mounted in it. The time required for completing such a gun, supposing no unforeseen delay to occur, is fifteen months. Ranged in a row, on the opposite side of the shop to that occupied by the lathes, are the boring and rifling machines for the largest calibers, the last-named operation for the 66-ton guns just referred to occupying for each fifty days.

The extent of the gun-factory may be judged from the fact that there are in it 10 such lathes as the one illustrated, capable of taking masses of steel up to 46 ft. in length, and weighing 100 tons; and 2 rifling machines for similar calibers. For smaller sizes, there are 20 lathes taking in work from 20 to 30 ft. in length, and weighing from 10 to 20 tons; 2 corresponding rifling-machines complete this section of the plant. Of miscellaneous tools, for planing, screwing, and slotting, there are of course a large number. The smaller bays are devoted to lighter work: field and mountain artillery, small mortars and siege-guns, and projectiles.

Lathes, Turret (see also Screw Machines).—*Jones & Lamson's Turret-Head Lathe.*—Figs. 15 to 22 illustrate a turret-head machine, which embodies several departures from the regular practice in such machinery, enabling certain classes of

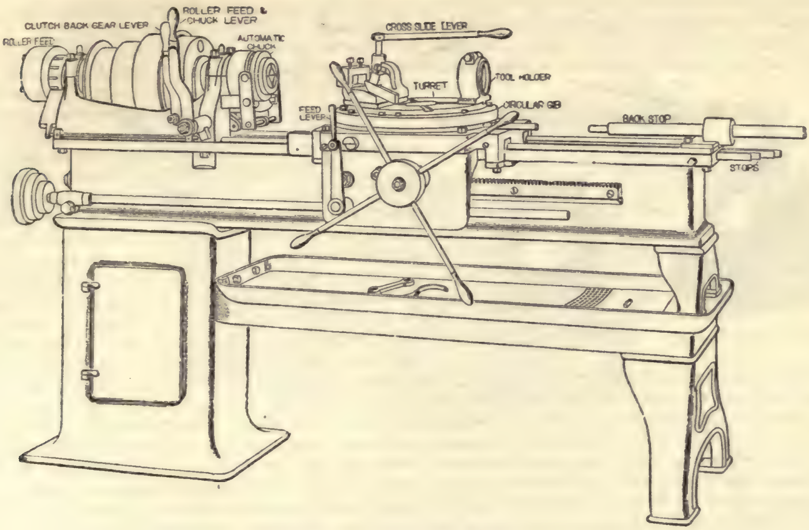


FIG. 15.—Turret-head lathe.

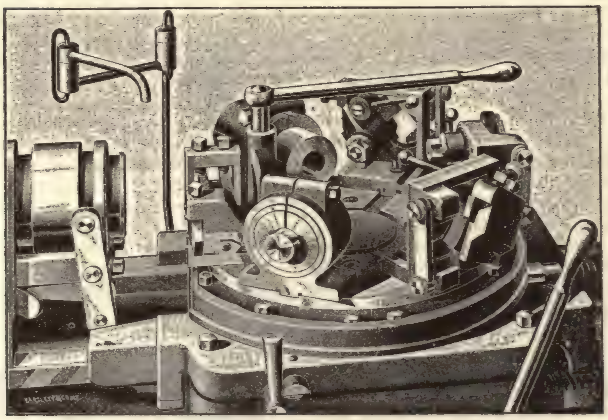
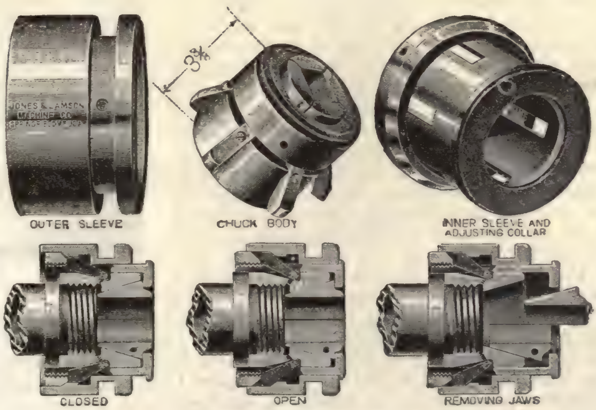


FIG. 16.—The turret.

FIG. 17.—The turner.



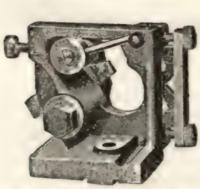


FIG. 18.—The turner.

FIG. 19.—Chuck—details.

work to be done on it that have not heretofore been attempted on turret-head machines. It is built by the Jones & Lamson Machine Co., of Springfield, Vt.

The usual form of turret and mounting for the same has been entirely abandoned, and what may be termed a turn-table is mounted upon what resembles the ordinary lathe-carriage. This carriage is fed by rack and pinion with pilot-wheel in the ordinary manner, or automatically, as may be desired, and the turret revolves automatically. The carriage slides on large 90° Vs, and is gibbed to the bed outside front and back. The various tool-holders, turning devices, cut-off slides, etc., by which the work is done, are simply attached to the top or upper surface of the turret by square tongues and grooves with bolts. The turret, which is proportionately much larger in diameter than usual, is gibbed all round its outer circumference, and the locking-pin engages there. The cutting-tools do not extend out over the turret, but are usually about vertically over the point of engagement of the locking-pin, a fact which practically relieves the central bearing of the turret of all stress during the cut, and enables the tool to be held more steadily, other conditions being the same. There are six slots for as many tool-holders, and there is a separate stop for each one, which is adjustable independently of all the others, so that the point at which the feed will be automatically released, and the motion of the slide positively arrested, may be independently fixed for each tool and operation, instead of its being necessary to set all the tools but one to suit the point of feed-release. The revolving mechanism is also arranged so that it can be made to act at the moment any tool clears the work, so that no loss of time results from running back farther than is necessary for any given tool. Where less than the full number of tools are used, the revolving mechanism can be made to skip one or more places, so as to bring the next tool into position wherever it may be. Fig. 15 is a perspective view of the machine, and Fig. 16 is an enlarged view of the turret, with six tools set upon it. While the ordinary turret-head lathe or screw-machine will distance the lathe for work to which it is adapted, it has its limitations, one of these being that there must be a comparatively large number of pieces to make that are just alike, otherwise it will not pay to set the various tools and arrange the machines for doing the work; the number of pieces needed to make it pay to do this depending mainly upon their character. This difficulty the builders of this machine have attempted to overcome by arranging the tools so that they can be set with a facility approaching that of lathe-tools; and it is claimed by them that, if there is but one piece to do, it will usually pay to do it on this machine, and that it is therefore well adapted to general machine shop-work within its range of capacity, which is for work up to 2 in. in diameter and 24 in. long.

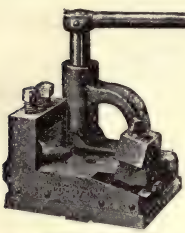


Fig. 20.—Cut-off slide.

Fig. 21.—Tool-holder.

Turret-head machines have not heretofore been constructed for work of this length, nor for doing work so long in proportion to its diameter as can be done on this machine.

Long work of small diameter is finished by means of the tool shown in Figs. 17 and 18, the former being a front view and the latter a rear view of the tool, which is called the "turner." The tool is adjustable by screws, and can be moved to or from the work by a cam, which is moved by a small lever, so that the tool may be run into the work for necking, or, in the case of long and slender work, the tool is opened, run up close to the chuck, where the work is held securely, and the tool run in to the required depth. It is then fed backward toward the end of the work, the usual back-rest following behind the tool, and bearing on that portion of the work that has been trued. In this way much of such work is finished at a single cut from the rough, though where it is necessary another cut can be run over it in the other direction, the rest in this case, as in the other, following the tool. The cut-off slide, a separate view of which is shown at Fig. 20, is bolted to the top of the turret, as shown by the rear view of the machine, and is so arranged that the turret can be run up under the chuck, and the cut-off used without interfering with any of the other tools. Provision is made for using three tools in the slide, and as they have the longitudinal motion due to the movement of the turret, and can be fed into the work by a lever and small pinion, the three tools can be used for different purposes, such as necking in, cutting off, or turning if desired. The tool-holder for hollow mills, taps, dies, reamers, drills, etc., is shown by Fig. 21. It is attached to the turret in the same way as the other tools. The chuck used on the spindle is shown by the group of cuts (Fig. 23), which represent it in various positions and in detail. It can be opened and closed without stopping the machine by the movement of the lever designated "roller-feed and chuck-lever" in the outline

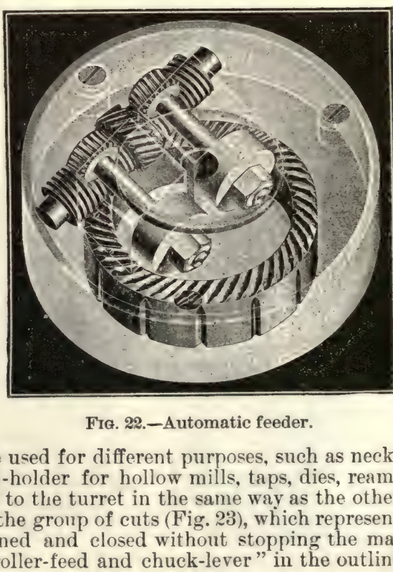


Fig. 22.—Automatic feeder.

view (Fig. 15), this lever, by suitable connections, being made to slide the collar on the outside of the chuck which opens and closes the collet in the manner indicated in Fig. 23.

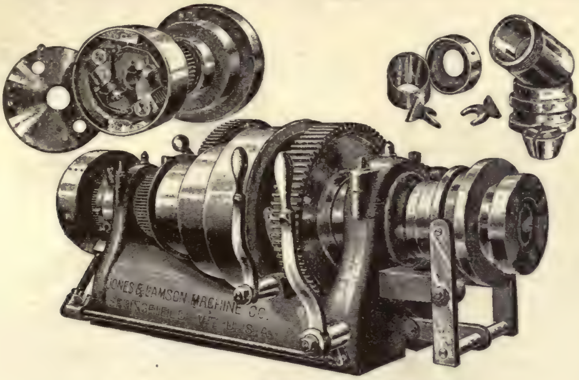


Fig. 23.—Roller-feed and automatic chuck.

The same lever is connected to the automatic feeding device (Fig. 22). There are two rollers that bear on the stock, one at each side. These, while a cut is being taken, serve to steady the work and hold it central in the spindle. When the lever is moved to open the chuck, and its motion is then continued in the same direction, it moves a plunger which engages with one of the V-grooves on the spiral ring-gear (Fig. 22), preventing it from turning. The spindle of the machine, continuing to turn, carries the spiral pinion with the two worms, worm-wheels, and feed-rolls with it, and by this motion about the spiral ring-gear they are made to rotate on their own axes, and the stock is thus fed forward through the chuck to the stop, and held there until the chuck is again closed.

The principal dimensions of the machine are: Working length, 24 in.; hole through spindle, 2⅛ in.; diameter of turret, 16 in.; swing over bed, 16 in.; width of belt used, 3½ in.; length of bed, 6 ft. 8 in.; weight, 2,600 lbs.

Turret-Lathe with Roller-Feed and Automatic Chuck.—Fig. 23 shows the revolving roller-feed and automatic chuck, built by the Jones & Lamson Co. for their turret-lathe and screw

Fig. 24.—Turret-lathe with roller-feed and automatic chuck.

machines. Fig. 24 shows the turret-lathe with the feed and chuck applied. The operation is as follows: The lever near the head is pulled forward; this opens the chuck, at the same time starting the roller or wire feed, and the stock is rapidly fed up to the stop-gauge; when the lever is thrown back the roller-feed stops, and at the same time the chuck closes firmly upon the stock, and the next operation is ready to be performed. This is done with two strokes of the lever, without the operator leaving his post and without stopping or reversing his machine. (See also Screw-Machines.)

Turret Chucking-Lathe.—Fig. 25 shows a 36-in. turret chucking-lathe made by the Lodge & Davis Machine Tool Co., of Cincinnati. This lathe swings 36 in., is back-geared, with power-feed, and has an 8-ft. bed. The cone-pulley has four changes for 3¼-in. belt; largest speed is

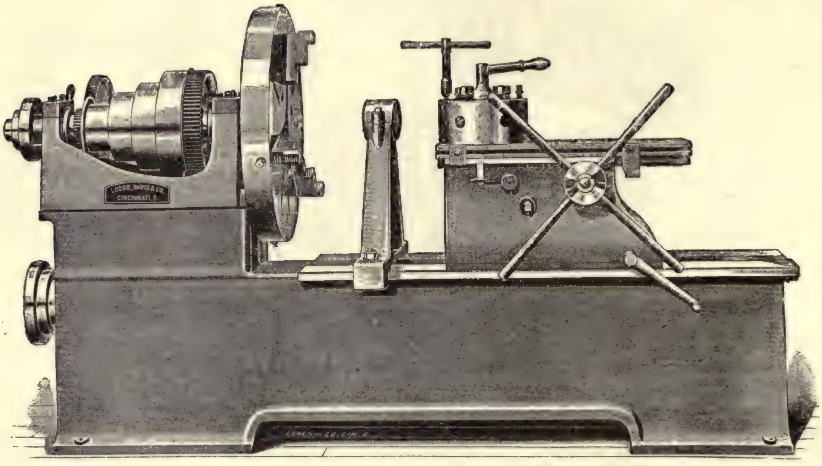


FIG. 25.—Turret chucking-lathe.

14 in. in diameter. The spindle is of steel, with 1⅞-in. hole through its length, and runs in bearings of phosphor-bronze; the front bearing is 3⅝ in. in diameter, 5½ in. in length. The turret is 12 in. in diameter, revolves automatically, and has 6 holes bored 1¼ in. in diameter. The turret-slide is operated by a pilot-wheel, and is provided with adjustable automatic stop to the power-feed, and will bore holes up to 13 in. in length without resetting. The turret-slide is actuated on the shears by rack and pinion. The feed is thrown in and out on the front side of the turret. A friction counter-shaft with reverse motion is provided, in order that taps and dies may be used.

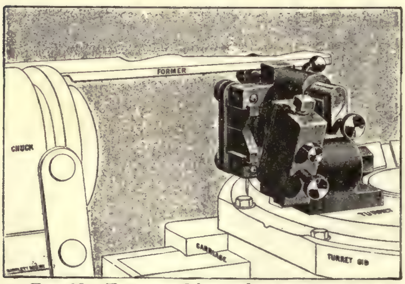


FIG. 26.—Taper and irregular turning-tool.

LATHE-TOOLS.—*Taper and Irregular Turning Box-Tool for Turret-Lathes.*—This tool (Fig. 26) is for the accurate turning of taper pins and bolts of all kinds and irregular shapes, such as handles, etc. The sliding template shown in front is a bar of steel, with its under-side of the exact taper required. The point of the screw beneath bears on a shoe, which in turns bears on the template. This screw passes through an arm of the rocking tool-carrier. The pin at the head end of the sliding template is held by a projection on the carriage. The carriage is set in the proper position, so that, when the power-feed of the turret is thrown in, for either direction, the tool advances or recedes, while the template remains stationary. The point of the cutting tool is thus swung out or in, and the exact taper or form of the template given to the piece turned.

LATHES, WOOD-WORKING. Improvements in this machine during the past ten years are mainly in its adaptation to special kinds of work. A variety of novel forms of lathe are presented.

Back-knife Lathe.—In this machine, which is for circular turning, there is a live and a dead center for the stock, and a centering device which may be put at any desired place in the length of the piece. Some of the work is done by ordinary turning-chisels, having adjusting screws so that they may be set accurately as to the diameter of the stock being turned, and V and gouge chisels, which are automatically lifted from a form on the return of the carriage bearing them. But the principal feature of the lathe, and the one from which it is named, is a back knife, as long as the stock to be turned, and sliding in vertical ways at the back of the lathe; this knife being either straight-edged and in one piece, or sectional, and made to do turning and scoring at various points of its length. It is set with the width of its blade vertical, and the length inclined to the horizontal, so that it makes a shearing cut, from one end of its length to the other, operating from one end of the stock to the other.

Gauge-Lathes.—In some gauge-lathes employing a pattern of the same general outline as the finished product is to be, the "former" is placed upon the frame which carries the stock, but at a greater distance from the center, necessitating its being of a greater diameter and all its dimensions exaggerated. In others it is placed in actual line with the stock; and in such case it may or may not be of the same diameter; but, whether it is or not, its outlines should

be parallel to those which it is intended to produce in the finished piece. With such an arrangement as this the same form may be made to produce several diameters of finished pieces, by adjusting its height; all the finished pieces coming of the same outline.

In one type of gauge-lathes, made by the Trevor Manufacturing Co., the form is a sheet-metal pattern, placed edgewise along the machine, and its curved upper outlines cause a rocking back and forth of the cutting-knives, which are given traverse along the stock, as the latter is rotated between the live and the dead center by a weight and cord feed.

A simple gauge-lathe (represented in Fig. 1), for turning all sorts of irregular forms, consists of an iron frame with planed ways, upon which are head and tool stocks, a tool-rest, and

Fig. 1.—Gauge-lathe.

an apron traversing back and forth by a screw. The head-stock carries a spindle, a cone-driving pulley, and a small feed-pulley. There is a self-centering attachment, which receives and centers the material without stopping the lathe. The tool-stock center rotates with the turning-stock, making both centers live. The tool-rest, which is gibbed to the planed ways of the frame, carries three cutters and a supporting ring, and may be moved either by hand or automatically fed by a heavy screw speeded from the head-spindle. The patterns are cut from sheet-iron of the exact profile of the finished article. As the work turns, the rest bearing the tools has lengthwise traverse, and is made to advance or recede from the center by

the sheet-iron form, thus producing articles of any desired contour, having all their sections circular.

The Ober automatic lathe for turning irregular objects, such as spokes, has a mechanism which automatically adapts the speed of the feed-screw and the rotation of the pattern and stock to the diameter of the work being turned. This mechanism consists of a small friction-pulley, which, lying between two reverse cones and being caused to slide along their faces by a trip-lever and connecting-rod, transmits a variable velocity to the train of gears rotating the feed-screws, pattern, and stock.

One variety of the Blanchard spoke-turning lathe has a horizontal frame or table with a lengthwise opening, through which vibrate the two end members of a frame which bears the stick from which the spoke is to be cut, and the solid iron form which is to be copied; these two being parallel, the form above the stock. Both the form and the stock are mounted between centers, and have rotation at the same speed, by gearing driven by belted connections from below. At the back of the table, which has planed ways, is an upright, carrying cutters rotating upon a horizontal axis lengthwise of the machine and parallel, of course, to the axes of the stock and form. A projection on the frame bearing the cutter-head bears on the form and vibrates the frame from or toward the axis of the cutters, according as the form is greater or less in diameter. The carriage bearing the cutters has a lengthwise traverse, given by a cord and worm-feed. The vibrating-frame is pivoted on an axis below the table instead of above, as was at first the case with machines of this class. It may be thrown into position by a hand-lever at the right of the machine, doing away with the necessity of the operator going to the opposite end of the machine to adjust the carriage and centers to proper position every time a spoke is turned. The spoke-centers always stop with the form at a fixed or determined point, ready for the insertion of the unturned spoke. The movable center is worked by an eccentric lever capable of holding the largest-sized spokes. The vibrator is held in position against the pattern and spokes by heavy adjustable springs.

An automatic spoke-lathe brought out by the Egan Co., and shown in Fig. 2, combines the principal features of the Blanchard lathe with new ones. The bed or frame is wider than is usual, and the "V" is placed some distance back of the center line of the cutter-head, allowing the belt to press the front of the carriage down to the "V" as it travels along. The construction of the bed is such that chips are not liable to accumulate on the top to obstruct the rollers. There is a sliding-carriage having four rollers, with their journals held in position by collars on the outside; the carriage has adjustable gibs to the main frame, to prevent side play. The standards carrying the cutter-head are bolted to the carriage on planed surfaces. The head has a combination of hook and gouge knives. The vibrating-frame is cast hollow, and is connected at the top by hydraulic pipe, to give strength and lightness. There are adjustable trunnion-boxes to change the size of the spoke. The gearing is cut from the solid, and the center gear has double width of face, to permit the operator to change the shape of the spoke. The back center gearing is so constructed that various lengths of spoke may be turned from one pattern.

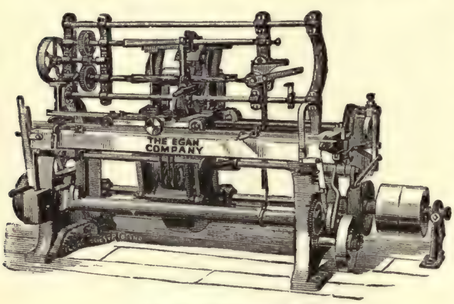


Fig. 2.—Spoke-lathe.

An improvement recently added is for automatically lifting into the cut the frame carrying the spoke, so that all the operator has to do is to remove the finished spoke and put in the stick for a new one—not even leaving his position, but merely pulling a lever, which sets the vibrating-frame into the cut; then the carriage, with the cutter-heads attached, travels along the bed, completing the spoke, the vibrating frame throws forward, and the carriage and head return to the starting-point to cut another spoke. This is, of course, much more convenient than lifting the frame into the cut every time a spoke is turned. One of these lathes has a record, made in a spoke-factory in Mississippi, of 2,695 spokes per day of 10 hours, which is claimed to be the greatest record ever made on a spoke-lathe. The average capacity claimed for the new lathe is 2,200 to 2,400 per day—more than double the ordinary capacity of such machines.

The automatic spoke and handle lathe, shown in Fig. 3, is for turning and squaring wagon and carriage spokes, although it has adjustments for turning common, Sarven, or sharp-edged shapes, making either light hickory spokes or heavy ones for wagon, truck, or artillery wheels, up to 44 in. long and 5 in. diameter There is a rotating horizontal cylinder composed of rotating knife cutter-heads placed side by side to make up the length of the spoke, each head having three cutters of 3-in. face lapping over each other so as to form a continuous cutting edge over the entire length of the cylinder. There is a table in two parts, gibbed and sliding on the frame in angular ways, being moved to and from the cutters by either a hand or a foot lever. The upper part of this table supports the turning centers, and is pivoted to the lower half near the tail center by a steel pivot, in one of several holes in the table, on which it vibrates for oval turning. At the opposite end of the head-center spindle is a cast-iron cam of the shape that it is desired to turn, this cam riding against an upright shoe extending up from the lower table, and held snug against the shoe by a coiled spring. When the table is

moved toward the cylinder to where the turning is begun, an automatic feed slowly rotates the object to be shaped, and the cam rotating against the shoe oscillates the table in a path

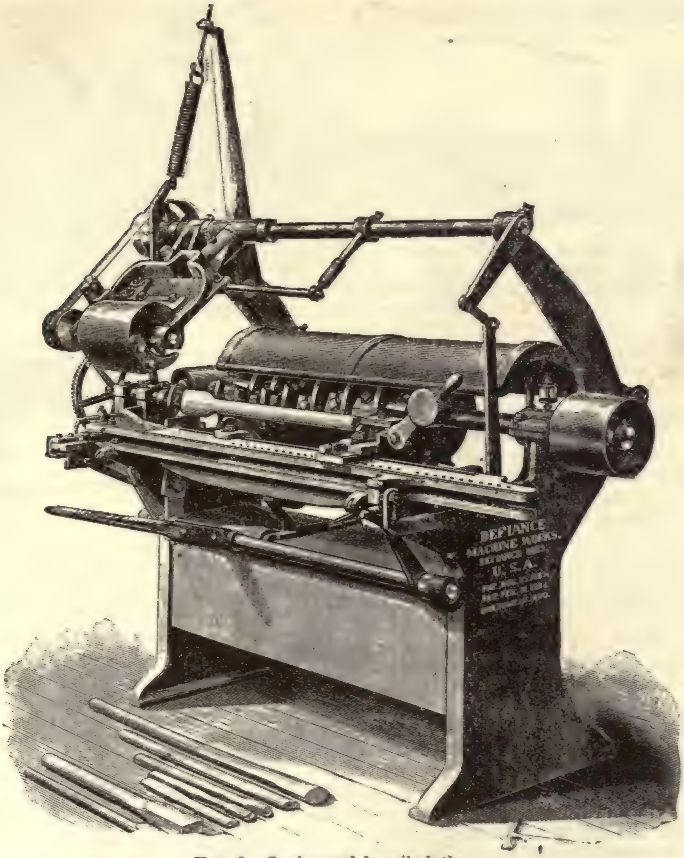


FIG. 3.—Spoke and handle lathe.

corresponding with the shape of the cam. When the pivot is placed directly opposite the tail center the machine will turn the work round at the tail end, gradually changing in section toward the other end, where it will correspond with the shape of the cam. For long, oval, or irregular turning, where both ends must correspond in section with the cam, the vibrating part of the table is locked fast with the lower part, and the cam rotates against a shoe fastened to the frame, thus vibrating both tables alike at each end. The diameter of turning is regulated by screws. The tail-center can be adjusted at any desired distance from the spur center for short or long turning, or at right angles for straight or taper turning. The swinging cutter-head is made to advance and retreat from the work automatically, its position being regulated by the movement of the table, the section turned being governed by a cam upon the live center table. It will turn square, octagonal, or any other section desired.

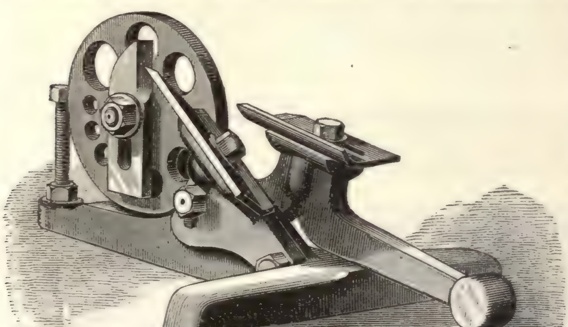


FIG. 4.—Rake-handle lathe.

A desirable attachment to any ordinary wood-lathe, that is sufficiently strong for turning rake-handles and similar pieces, is a concentric slide, shown in Fig. 4. It consists essentially of a circular plate having through it a number of circular holes of graded sizes, the centers of all of them being the same distance from the center of

the disk itself, which rotates on a horizontal axis. The article turned is finished to correct form by a knife on a swinging arm, which passes over a pattern fastened to the lathe-shears in front.

LATHE-TOOLS, METAL-WORKING. The accompanying engravings illustrate the most recent forms of metal-working lathe-tools. Fig. 1 shows a lathe threading-tool as made by the Morse Twist Drill & Machine Co. The holder of this tool is slotted, forming jaws, between which the circular cutter is firmly held by a bolt passing through the jaws and the cutter. The cutters are furnished to the V. or U. S. standard thread, singly or in sets, as desired. They are readily removed from the holder. The roughing cut for a thread may be taken with one section of the cutter and the finishing cut with another, the cutter being revolved in the holder, which need not be removed from the tool-post of the lathe. The cutters are quickly sharpened by grinding the faces.

Fig. 1.—Threading-tool.

Fig. 2 shows the Gardner & Woodbridge threading tool and holder, together with a series of tools for other purposes than threading, adapted for the same method of holding and sharpening. The holder is made of tool steel, hardened throughout and finished true, giving the same clearance for each tool. The single-point cutters accompanying are hardened and ground to produce an angle of 60° exactly, with the proper width of flat for the pitch of thread (U. S. standard) that each is intended to cut; simply grinding the top of the cutter parallel with the top of holder when sharpening being all that is required to keep the angle and width of flat at the point correct. The same single-point cutter is used for right and left hand threads.

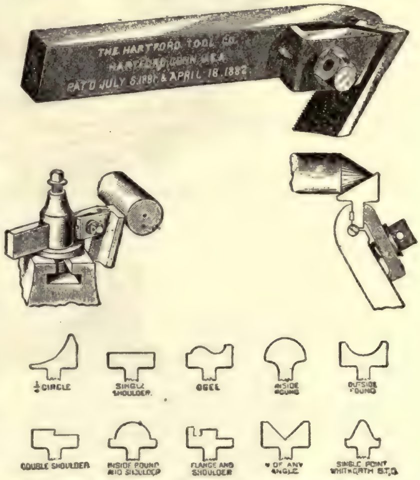


Fig. 2.—Threading-tool and holder.

Fig. 3 shows the Woodbridge lathe and planer tool. The tool is made to shape, thus saving the forging and grindings necessary with ordinary tools. Being supported and backed up close to the cutting-edge, and having no vertical projection, it will stand heavier cuts and faster feeds than ordinary tools. The new tools can, without alteration of form, be used in a planer as well as in a lathe. If the tools are kept ground in stock, the workman has but to slip in a new tool as the old one becomes dull, no adjustment for height being necessary, as in the forged tool.

Fig. 3.—Lathe and planer tool.

Johnson's cutting-off tool, for lathe, planer, and screw machine use, is shown in Fig. 4. The holder in this tool is a plain rectangular piece of machine steel, case-hardened, with recess

Fig. 4.—Cutting-off tool.

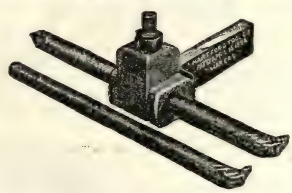


Fig. 5.—Boring-tool.

in side, having the edge beveled to hold blades, which have their edges beveled to correspond to the holder. The small screws at each end are to insure a tight fit to the blade when in use, and to hold the blade when grinding. This tool may be used for planer or lathe work.

Fig. 5 shows a boring and inside threading tool. Fig. 6 shows a lathe-tool, which has but

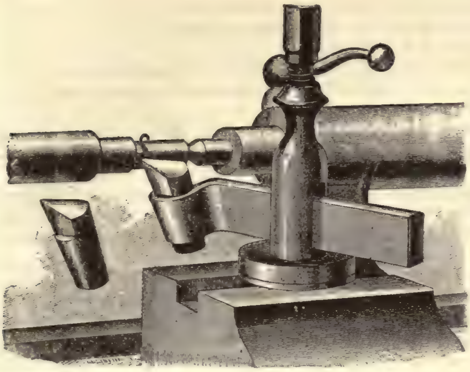


FIG. 6.—Lathe-tool.

FIG. 7.—Center reamer.

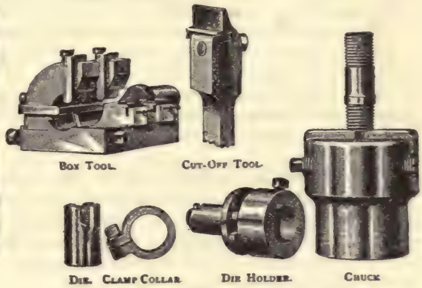


FIG. 8.—Turret-lathe tools.

FIG. 9.—Knurling tool.

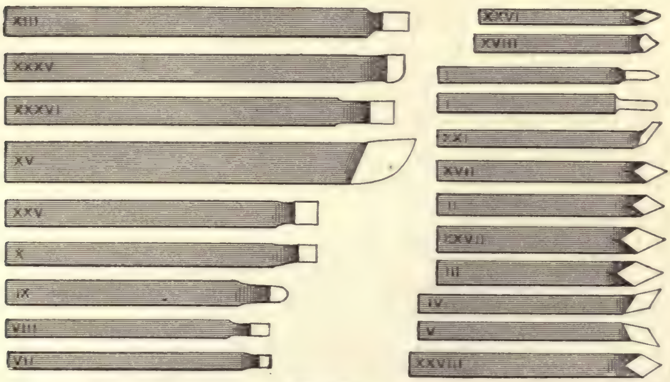


FIG. 10.

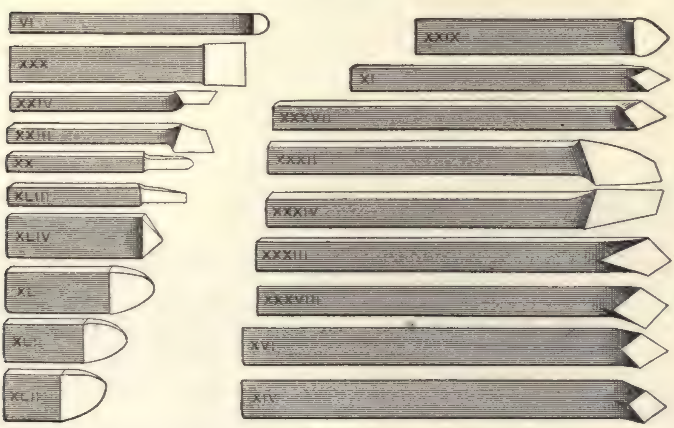


FIG. 11.

FIGS. 10, 11.—Cast-iron tools (see list).

two parts—the holder, which need not be removed from the tool-post, and the cutting-point, which requires only to be placed in position when it is ready for use, its removal being effected by giving the projecting point a slight turn with a wrench.

Fig. 7 shows a new style of center reamer. It is fluted with three cuts, and the cutting edges are relieved. It will in all cases make a round hole, which is not always the case with the old-style one-cut reamer.

The usual set of tools now used for a turret-lathe is shown in Fig. 8. These consist of one hollow mill and holder and one or two box-tools, one or two die-holders and dies, one cutting-off tool, and one stop-gauge.

The knurling-tool, shown in Fig. 9, is designed for checking cylindrical pieces that they may be held firmly by hand. The holder is jointed, that the knurls may center themselves, and be used in a weighted lathe without an extra weight being applied to the carriage to hold it in position.

Cast-Iron Lathe-Tools.—Cast-iron tools for cutting metals have been successfully used in the Pennsylvania Railroad shops at Altoona, and in the shops of the Ferracute Machine Co., at Bridgeton, N. J. They are made to the ordinary standard shapes used for forged tools, as shown in the accompanying diagrams (Figs. 10 and 11), which are copied from those used in the Altoona shops. The names, functions, and dimensions corresponding to the numbers are given in the following

List of Cast-Iron Tools.

Number.	Name.	Dimension, inches.
*I.	Round nose for iron and brass	$1\frac{3}{8}$ by $\frac{5}{8}$ by $8\frac{3}{8}$
†I.	Thread-tool for wrought and cast iron	$1\frac{3}{8}$ by $\frac{5}{8}$ by $8\frac{3}{8}$
II.	Diamond point, right-hand, for lathe	$1\frac{3}{8}$ by $\frac{3}{4}$ by $8\frac{1}{2}$
III.	" " "	$1\frac{1}{2}$ by $\frac{7}{8}$ by $8\frac{1}{2}$
IV.	" side-tool, right-hand, for lathe	$1\frac{1}{8}$ by $\frac{5}{8}$ by 9
V.	" " " "	$1\frac{1}{8}$ by $\frac{5}{8}$ by 9
VI.	Round nose for lathe or planer	$1\frac{1}{2}$ by $\frac{13}{16}$ by $9\frac{3}{4}$
VII.	Square nose for planer	$1\frac{1}{4}$ by $\frac{11}{16}$ by $10\frac{1}{4}$
VIII.	" for lathe	$1\frac{3}{8}$ by $\frac{3}{4}$ by 10
IX.	Round nose for lathe or planer	1 by $1\frac{7}{16}$ by $10\frac{5}{8}$
X.	Square " "	$\frac{7}{8}$ by $1\frac{1}{2}$ by $11\frac{1}{2}$
XI.	Diamond point for lathe or planer	$1\frac{1}{2}$ by 1 by $11\frac{3}{4}$
XIII.	Square nose for lathe or planer	2 by $1\frac{1}{8}$ by 15
XIV.	Diamond point for lathe or planer	$1\frac{1}{2}$ by $1\frac{1}{2}$ by $15\frac{5}{8}$
XV.	Oyster-knife for planer	$1\frac{1}{2}$ by $1\frac{1}{2}$ by $15\frac{1}{4}$
XVI.	Diamond point for planer or lathe	$1\frac{1}{2}$ by $1\frac{1}{2}$ by $15\frac{1}{2}$
XVII.	" " left hand	$1\frac{1}{2}$ by $\frac{7}{8}$ by $8\frac{1}{2}$
XVIII.	" for lathe	$1\frac{1}{8}$ by $\frac{5}{8}$ by 7
XX.	Round nose for lathe	$\frac{5}{8}$ by 1 by 7
XXI.	Boring-tool "	$1\frac{5}{16}$ by $\frac{5}{8}$ by $8\frac{3}{8}$
XXIII.	Left-hand side or facing tool for lathe	$1\frac{1}{8}$ by $\frac{5}{8}$ by 8
XXIV.	Right " " "	$1\frac{1}{8}$ by $\frac{5}{8}$ by 8
XXV.	Square nose for planer	$1\frac{1}{16}$ by $1\frac{1}{2}$ by $11\frac{1}{2}$
XXVI.	Diamond point for lathe	$1\frac{1}{8}$ by $\frac{1}{2}$ by $6\frac{3}{4}$
XXVII.	" " or planer	$\frac{7}{8}$ by $1\frac{1}{2}$ by $8\frac{1}{2}$
XXVIII.	" for planing and facing cylinders	$\frac{15}{16}$ by $1\frac{3}{8}$ by $9\frac{3}{8}$
XXIX.	" for planer or facing-mill	$1\frac{1}{4}$ by $1\frac{1}{4}$ by $9\frac{1}{8}$
XXX.	Square nose for turning cylinder flanges	$1\frac{3}{8}$ by $1\frac{3}{8}$ by 9
XXXII.	Side-tool for axle-lathe or planer	2 by 1 by $14\frac{1}{2}$
XXXIII.	Diamond point for axle-lathe or planer	2 by 1 by 15
XXXIV.	Side-tool " " "	2 by 1 by $14\frac{5}{8}$
XXXV.	Square nose " " "	2 by 1 by 15
XXXVI.	" " " "	2 by 1 by $14\frac{1}{2}$
XXXVII.	Diamond point for planer	$1\frac{1}{2}$ by $\frac{7}{8}$ by $14\frac{1}{2}$
XXXVIII.	" for axle-lathe	2 by 1 by 15
XL.	Tools for boring cylinders (Baldwin)	$1\frac{1}{2}$ by $1\frac{1}{2}$ by $5\frac{3}{4}$
XLI.	" " "	$1\frac{1}{8}$ by $1\frac{1}{2}$ by $4\frac{3}{4}$
XLII.	" " "	$1\frac{1}{2}$ by $1\frac{1}{2}$ by $3\frac{5}{8}$
XLIII.	Square nose for lathe	$1\frac{1}{4}$ by $\frac{3}{4}$ by $6\frac{3}{4}$
XLIV.	Boring-tools for driving-boxes	$1\frac{5}{8}$ by $\frac{11}{16}$ by 6

For a given size of cut, the shank of one of these tools should be somewhat larger than in the case of a forging, in order to give the required lateral strength where it is fastened in the tool-post. Otherwise the shapes and sizes may be exactly the same. In general, heavier cuts and probably somewhat higher speeds can be taken with these tools than with forged steel ones, for the reason that there is no danger of drawing temper by the heat due to cutting-friction. The experience of the Pennsylvania Railroad Co. shows that, on the whole, these tools, cheaply made as they can be, are superior to steel tools for roughing-cuts, but that they are not desirable for finishing-cuts.

* The lower of the two tools thus numbered. † The upper of the two tools thus numbered.

The construction of these tools is of the simplest description. An ordinary wooden pattern of the exact shape desired is molded in the usual way, with a small portion of its cutting point in a cast-iron chill. A tool can not, of course, be repaired in the blacksmith-shop, but must be melted up when worn out. They can be so cheaply recast that their maintenance, as well as their original cost, is much less than that of the ordinary forgings. The best composition of metal, as far as has been ascertained, is the same as for car-wheels, and no particular care is necessary in regard to the method of pouring or the heat of the melted metal.

Leaching-Vat: see Mills, Silver.

LEATHER-WORKING MACHINERY. *The Goodyear Method of Sewing Shoes.*—Among many different methods of sewing and stitching welted shoes, and sewing turned shoes, may be mentioned the Goodyear method. In the welt system, the machines employed are an in-seamer for sewing the welts, an out-sole stitcher for stitching the sole to the welt, a machine for preparing the welt, a machine for beating out the welt, and chaneling-machines.

The curved awl and the curved needle are employed, and the lock-stitch is used. The out-sole stitcher is now a lock-stitch machine, which stitches in any kind of channel, or "aloft" if desired. In either case it shows the "fair-stitch," or the welt and out-sole in perfect imitation of hand-work. The tension of the machine is regular and uniform. The in-seaming machine, instead of the "pull" of the tension being outward from the central line of the inner sole, as was formerly the case, the stitch is now set with an inward pull toward the central line of the inner sole, practically the reverse of the old method, and the tension is drawn exactly as in hand-work. In this work, as the awl feeds the shoe, the looper passes the thread in front of a thread-finger, which finger retains it until the looper conveys the thread around the needle. The needle then draws the thread through the sole and welt outward, and, as the machine feeds again, the needle starts forward to make another stitch, and the take-up then begins to draw in the slack thread as the needle completes the stitch. In sewing turned shoes, the new machine draws the thread up and around the needle while the latter is in the stock, thus setting the stitch without stretching the sole. By the same

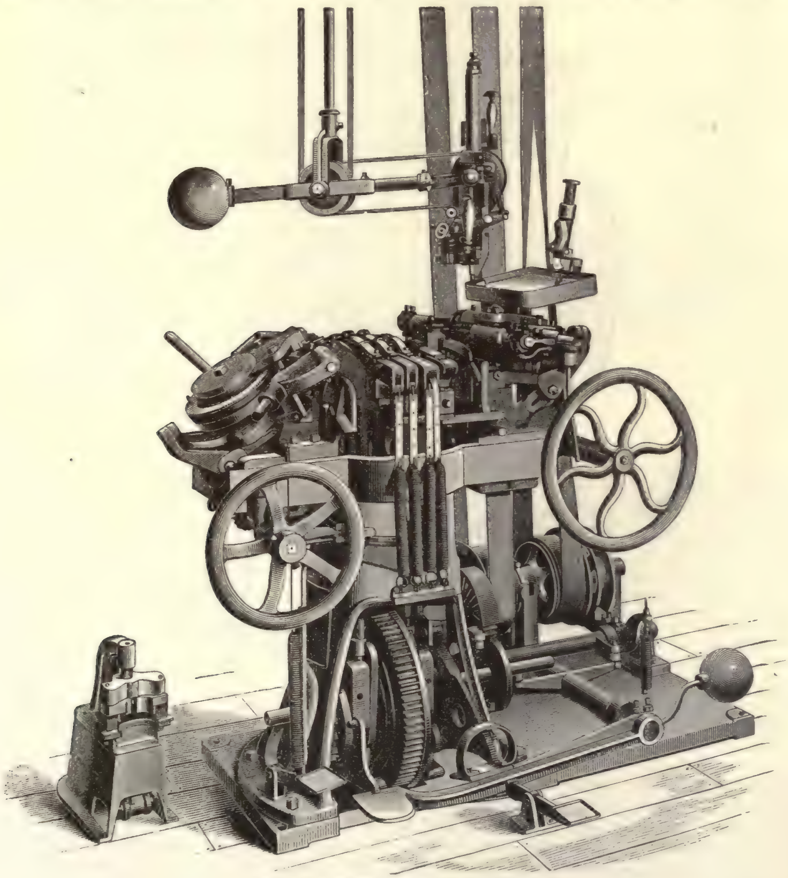


FIG. 1.—McKay lasting-machine.

device the pull of the tension is directed inward toward the last, avoiding thereby the strain in the between-substance, which occurs whenever the stitch is set by the needle, as was the

case in the old machines. This machine may be used on both welt and turned work by adjusting the welt-guide.

The McKay & Copeland Lasting-Machine and Accessories, for Lasting Boots and Shoes generally.—The important mechanical principles employed in this lasting-machine (see Fig. 1) are a universal adaptability of girth, heel and toe devices for drawing the upper, whether of light or heavy leather, snugly and evenly, and laying the same over and upon the inner sole without regard to rights or lefts, length or width, or as to spring, twist, or roll of the last. The novel mechanism includes: 1. A girth, apron or straps, yielding from its center and fastened at one end to fingers, which act as wipers, and at the other end to springs, for folding the upper around the last and laying the same over and on to the inner soles, ready to be attached. 2. An oscillating head, carrying toe and heel lasting mechanisms for lasting the toe and heel parts, ready for attaching to inner sole. And in its accessories, viz.: 3. A pinking device for removing the surplus stock to permit the laying over smoothly, upon inner sole, the leather at toe of boot or shoe, instead of hand-pleating it. 4. A suspended universal power-pegger, for attaching the upper to the inner sole with pegs, when the out-sole is to be pegged on. 5. A hand-tacker, supplied with a tack-strip (which is composed of a foundation strip, in which common shoe-tacks are stuck, and a covering-strip, which is stuck over the same to hold the tacks in place) from which tacks are driven to attach upper to inner sole, when the out-sole is to be attached otherwise than by pegs—that is, when to be soled, nailed, or screwed. This machine will last French or American calf, wax, kip, split, buff, grain, or glove upper leathers, with either a straight sole-leather or molded stiffener (heel-counter) for either pegged, nailed, standard screwed, McKay or Goodyear sewed boots or shoes. Sizes: men's, 5 to 13; women's, 3 to 9; boys', 1 to 6; and misses', 12 to 2.

The Chase Lasting-Machine (Fig. 2) is employed principally on men's medium or fine shoes, and uses the same tacker and tack-strip as the McKay & Copeland machine. It is

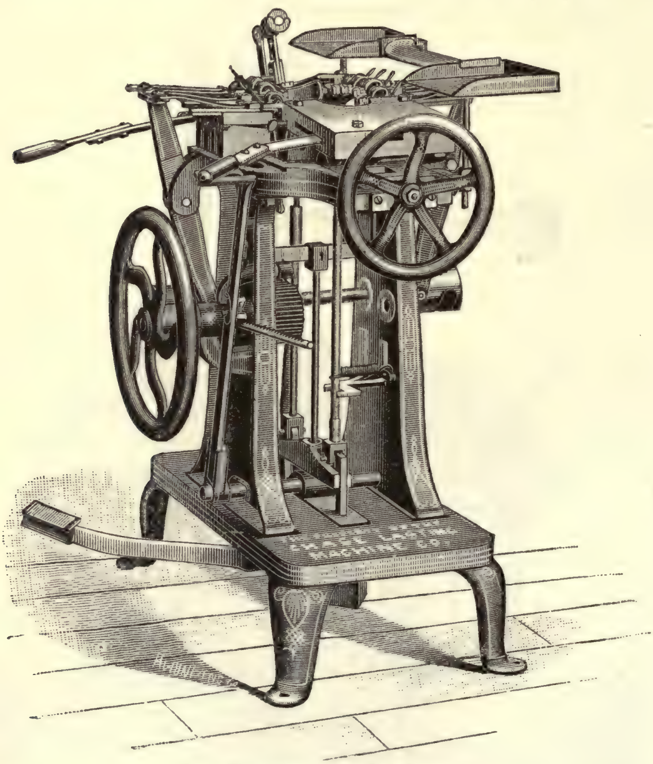


FIG. 2.—Chase lasting-machine.

a hand-power machine, which adapts itself to any style of last, no change being necessary whether a right or left hand shoe is to be lasted. The toe and heel plates are fitted for each style of shoe. The vamp has all the stretch taken out of it when going through the lasting process by a pressure on the foot-lever, which operates four nippers on each side of the last, each nipper working independently of the other, and taking out the stretch under its control. The toe of the last is pressed into the vamp, while the toe portion of the vamp is held between a wiper and a foot that is controlled by a hand-lever, which releases the pressure when the wiper is brought over the toe of the last.

An Electrical Sole-Sorter.—Wilder & Co., of Chicago, make a very ingenious electrical

sole-sorter, shown in Fig. 3. This machine determines the exact thickness of cut soles, taps, and bottom stock by electrical and mechanical devices, and distributes them automatically. This machine measures the thickness of the tap at the center, and not at the side, and, automatically determining the thickness, drops them into the proper box. The difference in quality, such as fine and hard, and coarse and soft, must always be left to the judgment of the sorter, but to determine by the eye the exact difference in the thickness of the different grades is not possible. To fully realize this, one must know how fine the difference is. Twelve

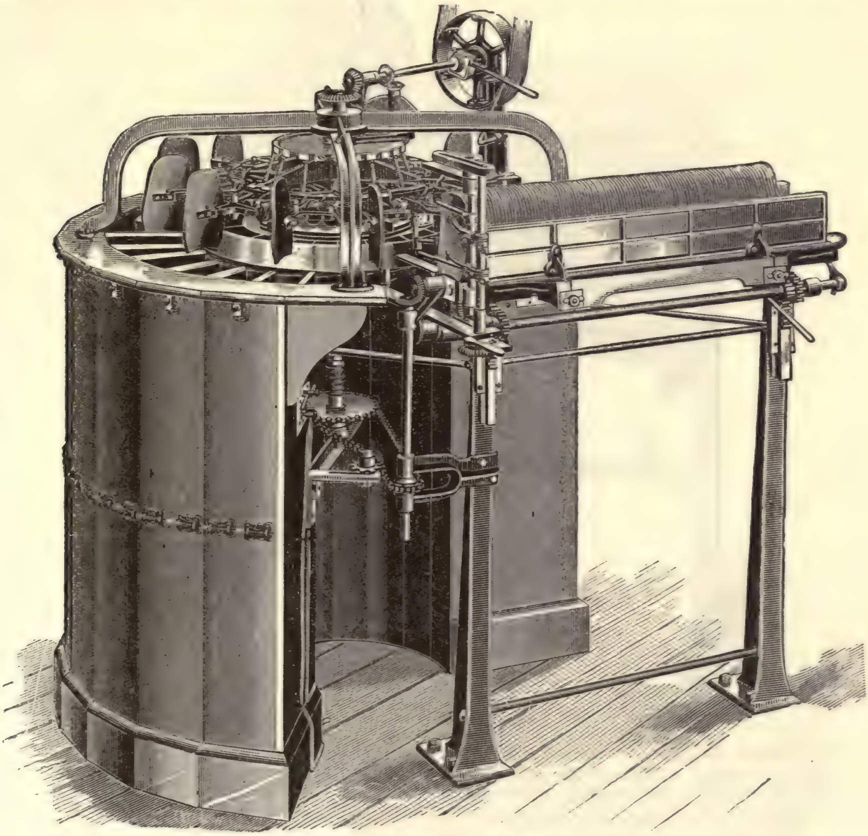


FIG. 3.—An electrical sole-sorter.

pairs of taps to stand just 6 in. high and be uniform in thickness, must each be just $\frac{24}{96}$ of an in. thick. If each were $\frac{25}{96}$ of an in. thick they would stand then $6\frac{1}{4}$ in. high. Thus it will be seen that $\frac{1}{96}$ of an in. constitutes a grade—that is, $\frac{1}{4}$ of an in. difference in the height of the dozen when tied up. This machine is so finely adjusted and so accurate that it can be set to grade down to $\frac{1}{1000}$ of an in., and can be depended on to do it every time. In selling taps much has been made of weight—that certain taps will weigh more to the dozen than those of another cut by a die of the same size, and the dozen standing the same height. This may be true, but it is of no account in fixing values, if we take into consideration the fact that leather tanned by the sweating process will weigh 10 per cent more to the side than that tanned by the lining process. Thus, it is not weight, but substance or thickness, that is the real standard of value—i. e., that in taps of the same quality, fine or coarse, it is not weight that tells, but thickness. The same parties make a small bottom-stock sorting-machine, worked by hand, which automatically and mechanically determines the exact thickness of bottom stock at the sorting-table. It is claimed to save a good part of what is usually wasted under the splitter.

The Hemingway Smooth-Rolling, Glassing, Pebbling, and Staking Machine will glass, buff, wax, calf, or sheep, without nipping or plaiting. There are four glasses or slickers, and when one leaves the bed there is one going on. For cutting over splits or staking morocco there is a foot-treadle, so that the operator can gauge the pressure to any thickness. There is an emery attachment to keep the slickers sharpened. The machine can be used for pebbling with one or two rolls. There is no back-stroke to catch the shanks. By changing the tools, taking about 20 min., it can be made to glass, pebble, cut over splits, run off grease, stake or brush.

The Duplex Hide and Side Worker is made for whole hides, sides, very heavy kip, and calf-skins, in widths of 9 ft. and 7 ft. 6 in.; it is built proportionately strong, to meet the extra

strain in working hides and side-leather. The machine will flesh and unhair at one and the same time, or either separately, doing the work without packing or damaging the hide or skin in any way. The cylinder can be arranged to cut the flesh in a clean manner, or to work it as in a breaker, thereby leaving the hide or side either soft and pliable, if for upper leather, or hard and firm if needed for belting, sole, or harness leather. This machine, it is said, will flesh and unhair with one operator up to 450 sides in one day of 10 hours.

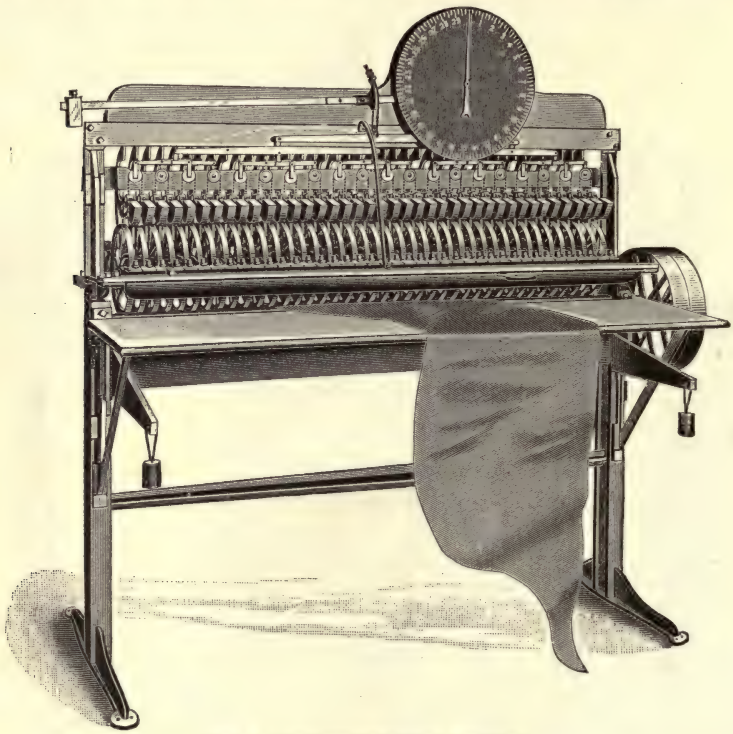


FIG. 4.—Leather-measuring machine.

The Sawyer Leather-Measuring Machine, shown in Fig. 4, mechanically measures leather or other superficial surfaces with great accuracy, and in any condition whatever, whether wrinkled or smooth. Its leading principle is a reduction by mechanical means of linear to square measure. The machine is a rotary one and requires very little power, and may be operated either at a fast or slow rate of speed. The article to be measured is laid on the inclined table, and its end fed in between a roller and a series of wheels, and, if it be wrinkled, is perfectly smoothed out as it passes beneath, so that the wheels may measure the exact surface that passes beneath them, transmitting their measuring movements to the dial, which, as the article continues to pass through the wheels, will gradually indicate its measurement. The machine is comparatively simple, and is constructed entirely of metal with interchangeable parts, and employs no springs—the movements being positive, and the motion of the measuring-wheels transmitted directly to the indicator.

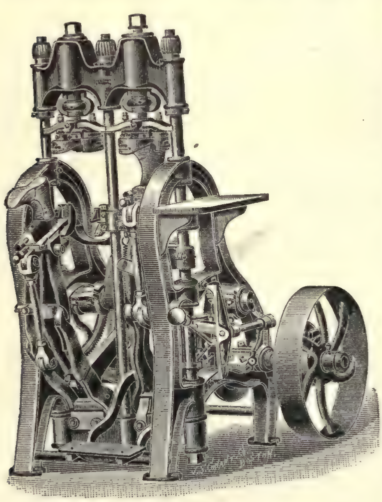


FIG. 5.—Sole-shaper.

The Brennahan Sole-Shaper (see Fig. 5) shapes the sole, after it is attached to the upper, to the desired lines and curves the trade may require. The machine is a twin machine, one side being usually used for rights and the other for lefts. The operation is effected by placing the boot or shoe upon one of the lasts attached to the machine. The operator then places his foot upon the treadle, and the last and shoe are carried automatically beneath a mold, the machine stopping when the shoe is under a heavy pressure and the toggles have reached their highest point. In the mean time the other last and shoe

LETTER-MARKING MACHINE.

which were under pressure will have come out from beneath its mold and stopped in front of the operator; this motion is continuous to the inward movement of the other last and shoe, and both movements are effected by the simple depression of the treadle. The operator then removes the shoe that has come from beneath the mold, and replaces it by another, again pressing the treadle to repeat the movements, and so on, thus giving all the shoes that are operated on uniform shape and style.

LETTER-MARKING MACHINE. On the opposite page is illustrated an automatic letter-marking machine recently adopted by the Post-Office Department of the United States for use in the post-offices. The machine, which is manufactured by the International Postal Supply Co., of New York, under the patents of G. W. Hey, Emil Laass, M. J. Dolphin, and August Bertram, combines the merits of speed, effective cancellation, uniform and legible post-marking, and an accurate registry of the number of letters and postal-cards operated upon. Recent tests in the New York Post-Office show that upward of 40,000 pieces of mail matter have been successfully operated upon within one hour. It is therefore probably the most rapid printing machine known. All of the operations of the machine, after the letters are inserted in the receiving-hopper, are entirely automatic. The letters are placed in a receiving-hopper, as shown in the engraving, and are fed consecutively to the mechanism for applying the post-mark and cancellation, and recording device for indicating the number of letters operated upon, and are compactly packed in a stacking or delivery tray, after the marking and counting operations are effected.

The mechanism for performing the different operations of feeding, separating, marking, recording the number of letters operated upon, and the final operation of stacking the letters, may be divided into three groups, namely, feeding and separating mechanism, the marking and counting mechanism, and the stacking mechanism. The feeding mechanism consists of a feed receptacle provided with a moving bottom, composed of an endless belt, which serves to carry the letters to a series of feeding and separating rolls arranged opposite to each other. The separating rolls rotate in the same direction relative to each other, so that their contiguous peripheries rotate in contrary directions; one roller of each series being driven with greater speed and rotating in the direction of the feed, to carry the letters forward, while the oppositely arranged roller of the series rotates with less force and feeds backward the letter next to its face, if more than one at a time emerge from the letter receptacle. The reason why the letters are consecutively presented by this feed is, that the roller which rotates in the direction of the travel of the letters is driven with greater speed and force than the conjointly acting roller arranged opposite to it. Hence the letter next to the roller, rotating in the direction of the travel, is carried forward with greater force than the letter lying next to it, which, if the two pass out of the feed receptacle together, encounters the reversely acting roller, and is therefore held back momentarily until the letter next to the feed-roller is carried past the reversely acting roller. It will thus be seen that but one letter at a time passes the separating rollers.

The marking mechanism consists of a curvilinear stamp secured to a stamp-roll loosely mounted on a rotating shaft so as to be normally at rest; this shaft carries a constantly rotating drum arranged to be engaged with the stationary stamp-roll by the action of a friction-clutch secured on top of the stamp-roll, and actuated by springs to expand when the clutch-jaws are released, and engage with the inner face of the constantly rotating drum when the clutch is operated by the contact of the letters with a trigger or pivoted lever, which lies in the letter-path, as the letters are presented to the marker by the action of the feed and separating mechanism.

The advancing end of the letter comes in contact with the tripping device in the letter-path, and the movement of the tripper releases the spring friction-clutch mounted on top of the stamp-roll, and the expansion of the clutch-jaws causes them to impinge the inner face of the rotating drum, thus connecting the stamp-roll with it, which is thereby caused to register on the moving letter.

The marking die or stamp is so placed on the stamp-roll as to commence its registry with the advent of the end of the advancing letter to the printing point, and an impression-roll, yieldingly journaled so as to permit letters of different thicknesses to be operated upon, serves as an impression-bed for the letter while the stamp-roll is registering therewith.

After the die has registered, it is stopped by the encounter of a pawl pivoted to the trip, with a pin on the clutch, which encounter releases the die from engagement with the revolving drum: at the same time an eccentric on the lower face of the stamp-roll is made to contact with a projecting stop, to prevent the stamp-roll from recoiling after the die has registered. The tripper, lying in the letter-path, is provided with springs which reset it immediately after the advancing end of the letter has passed the tripper, thus leaving the tripper in position for another operation on a succeeding letter, and establishing the proper conditions for the release of the clutch from its engagement with the continuously rotating drum when the stamp-roll is stopped in proper position to register on the succeeding letter.

The marking-die is supplied with ink, through the medium of a series of felt distributing rollers, the ink being provided from a rotating reservoir constructed with suitable vent-valves to regulate the flow of ink from the reservoir on to the felt distributors. Movable types are provided to change the date and hour of the post-marking die, and these consist of steel types set in a detachable radial-shaped type-box, which fits closely into an opening provided in the stamp-roll within the post-marking die, and the type-box is securely held in place by a spring which permits its release when it is desired to remove the same to change the date and hour.

The counting mechanism consists of a dial and indicator, and a series of synchronous

toothed disks operated by a pinion-wheel, that, in turn, is actuated by the cam on the stamp-roll disk, which, as it rotates, comes in contact with a crank-arm connected to the shaft operating the pinion-gear of the counter. As the stamp-roll rotates, the eccentric collides with the crank-arm lying in the path of its movement, and motion is transmitted to the pinion so as to register one revolution of the stamp-roll on the indicating dial, and consequently mark the passage of one letter.

The stacking mechanism consists of a series of push-arms radiating from a central hub carried on a rotating shaft arranged at right angles to the axis of the feed and printing-roller shafts, so as to feed the letters into a receiving-tray at right angles to the line of feed to the marking-stamp. The letters enter the delivery-tray through a pivoted chute arranged in close proximity to the marking and pressure rolls, and are received between a series of rubber-faced rollers rotating within the chute, and are thereby fed down to the bottom of the delivery-tray against a sliding stop, and are propelled forward by the rotating push-arms before described. The delivery-tray is inclined for the purpose of facilitating the packing of the letters as they are propelled forward by the push-arms. It will be observed that the marking-stamp rotates intermittently, invariably starting from a position at rest, when the tripper lying in the letter-path is moved by the advancing letter, and that the stamp-roll immediately stops after its registry with the letter, so that, no matter what the length of a letter may be, but one impression of the stamp is made on the letter in its passage between the marking and impression rolls; and, since the stamp-roll is only brought into operation to register with a letter after the letter has encountered the tripper, there is no ink deposited upon the impression-roll, and "offsets" on the reverse face of the letter are avoided, so that the registration of the stamp-roll is absolutely controlled on each and every letter automatically by the encounter of the letter with the stamp-tripper lying in the letter-path.

The principle or mode of operation upon which the marking mechanism depends is, that the letter itself controls its own marking by bringing the marker into operation to register thereon at the proper time and in the right place, and this principle is carried out in the mechanism by the arrangement of the parts as described, whereby the intermittent action of the marker permits the letter to receive the impression while in motion. All the devices are made adjustable, so that letters of indiscriminate sizes are readily operated upon, and, since there is no stoppage of the letter to make the impression, the speed or rapidity with which the machine performs its work is governed solely by the speed at which it is driven. In the post-offices a small electric motor from $\frac{1}{8}$ to $\frac{1}{6}$ horse-power affords ample power to drive the machine.

Link-Belts: see Belts.

Loader, Hay: see Hay-Loader.

Lock-Cutter: see Barrel-Making Machines.

Locked Coil Rope: see Rope-Making Machines.

LOCKS. Door-Locks.—*Yale Locks.*—A late improvement in Yale locks is the longitudinal corrugation of the key and corresponding alteration of the escutcheon, the plug in which is provided with a key-way having corresponding corrugations throughout its entire length, so that the key and key-way engage with each other at all points. A section of the escutcheon and corrugated key is shown in Fig. 1. This construction prevents tilting of the key, and renders access to the tumblers more difficult.

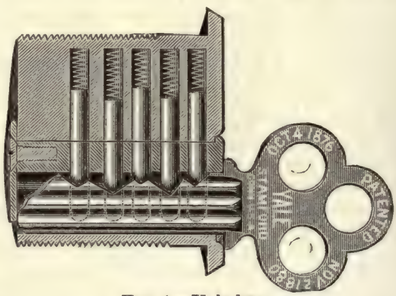


Fig. 1.—Yale key.

The Yale front-door lock, shown in Fig. 2, is so made that during the day the latch-bolt may be operated from without by a Yale corrugated key. At night the dead-bolt may be locked from within by another Yale key of different bitting, and under the latter circumstances the Yale key first mentioned will act, first, to unlock the dead bolt by making a full revolution, and then by a further movement to retract the latch. This arrangement gives the householder a single Yale key to operate both latch and dead bolts at any time, rendering it impossible for him to be locked out at night, and at the same time permits the house to be locked from within by a key which can not be used by any one to effect an entrance. The arrangement of parts will be understood by referring to Fig. 2. The dead-bolt A is made with a double tail and two dogging-levers B B connected together by a link. When either of the escutcheon-plugs is rotated, the cam C on the end of the plug will depress its dogging-lever and enter the corresponding talon, thus moving the bolt without regard to the position of the other dogging-lever. The latch-bolt G is operated by the bell-crank F, which is mounted on the bolt, so that when the dead-bolt is shot the tail of the bell-crank is out of the way of the cam on the escutcheon E (this being the escutcheon for the outside of the door), and hence

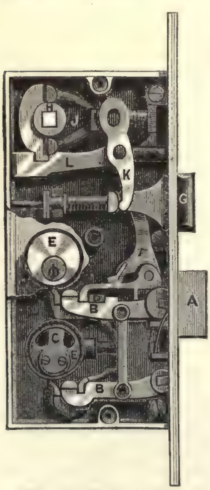


Fig. 2.—Door-lock.

the latch can be operated only by the key after the bolt has been retracted. The latch-bolt may be operated by the knobs at H, and these being provided with split-hub and swivel-spindle, the outside knob may be stopped by the stop-lever L. The escutcheon C is used only for locking the dead-bolt from the inside, and the escutcheon E makes a whole revolution to unlock the dead-bolt, and a further partial revolution to retract the latch; or, if the dead-bolt is not shot, the latter motion alone is made.

The Sargent "Easy Spring" Lock is illustrated in Fig. 3, which shows the interior mechanism. The construction is such that the bolt can be reversed so as to make the lock either "right" or "left hand" before it is applied to the door. The spring attachment causes the door to latch gently when closed. This consists simply of a stiff spiral spring so arranged as to operate under a long leverage on the latch-bolt, and at a direct pull on the knob.

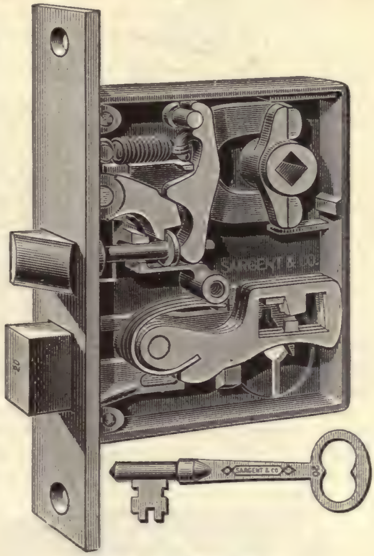


FIG. 3.—Sargent lock.

A Keyless Latch-Lock.—Fig. 4 shows a cross-section of a door exposing a keyless spring latch-lock, made by the Miller Lock Co., of Philadelphia, in place. The door may be unlatched from the inside by turning the knob shown in above cut, and the latch may be "thrown off" by the stayback. Light is not required in opening the latch from inside the door. From outside the door it is unlocked by turning the dial, as in opening an ordinary safe, but in less time, being necessary to turn once only to each of the three members of the combination.

MASTER-KEY LOCKS.—*The Yale Duplex Lock.*—The use of a master-key, by which a number of locks can be opened by one key in the hands of a janitor or other person in charge, while none of the individual or change keys will interchange, is a feature frequently demanded for hotels and similar places. The Yale duplex system is based upon the principle of using two independent and complete Yale escutcheons with corrugated keys in each lock, either escutcheon operating one and the same bolt. By making a series of these locks, in which all the lower escutcheons are set up to the same combination, it is evident that a key bitted to operate the lower escutcheon will be a master-key for the whole series, while, since the upper escutcheons are all set to different combinations, a key for any one of them will not operate any other of the series. The great number of permutations of which the Yale lock is capable permits an indefinite extension of the system, so that upward of 50,000 locks can be master-keyed in one series, by this system, to one master-key, while the security of the lock against picking or interchange of keys is not at all impaired.

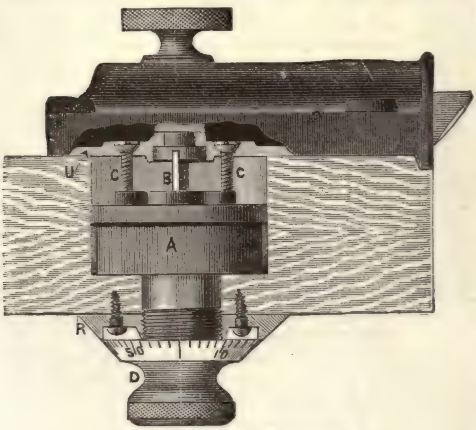


FIG. 4.—Keyless latch-lock.

The external appearance of a Yale duplex master-key mortise-latch is shown in Fig. 5.

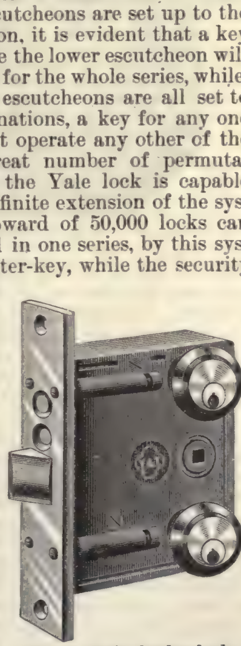
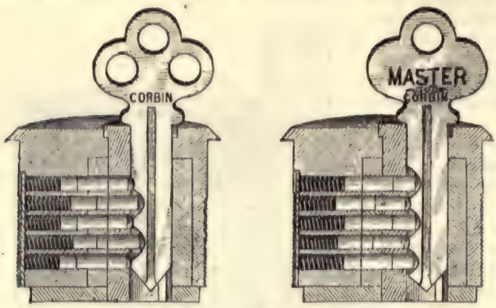


FIG. 5.—Yale duplex lock.

The Corbin Master-Key Lock, represented in Figs. 6 and 7, may be operated by either of two keys different in outline. The operation of the cylinders in connection with the drivers and pins will be rendered apparent from the illustrations. The pin-chambers in the cylinders being in line, the springs, operating through the drivers, maintain a downward pressure on the pins, in order that when the key is inserted through the slot the lower ends of the pins will enter the clefts of the key, and the upper ends of the pins and lower ends of the drivers will have a regular line of union at the meeting edges of the cylinders, thereby permitting of their rotation by means of the key. Thus the walls of the inner end of the slot will engage the sides of the other ward, and cause the rod to rotate, thereby bringing the arm of the revoluble plate upward into contact with the tumbler and bolt, and actuating said bolt either to lock or unlock the door. The pins, upon the with-

drawal of the key, will assume their normal positions with respect to each other. The minor key will be supplied to the tenants of an apartment-building, for example, and, while it will



FIGS. 6, 7.—Corbin master-key lock.

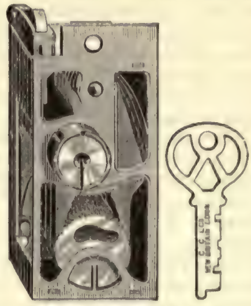


FIG. 8.—Post-office lock.

unlock the door prepared for it, it will be ineffective on any of the other doors of the building, the said other doors having locks in which the pins will vary in length, but all of which locks may be opened by a major key.

The Corbin Post-Office Lock-Box was adopted by the United States Government in 1888, upon recommendation of a special committee of experts, one each from the Treasury Department, Post-Office Department, and Patent-Office. A portion of their report is as follows: "The locking mechanism of the box possesses a capability of automatic adjustment on the part of the postmaster whereby, in the event of the loss or duplication of the key furnished the box-holder, an instantaneous change of said locking mechanism may be effected by the postmaster without the necessity of the removal of the lock-case, and a key of different form furnished the holder. The box itself has a metallic front, but instead of being made of wood is constructed of sheet-steel of smooth surface, plated and lacquered. By the use of this box more space is gained for mail-matter. The lock (Fig. 8) adjusts itself to whatever key may be inserted. Any change of key will lock it, but only the key by which it was locked will unlock it. Should a postmaster wish to give a box-renter a different change of key, the lock may be unlocked by the key then in use, and the bolt pressed to the end of the lock. This leaves the key in a directly opposite position from that when it is locked. By removing the old key and inserting a new one, the bolt may be thrown. When the keys are lost and the box is locked, in order to open the box a master-key is inserted inside the box from the rear, and the bolt is thrown from position, when the new key may be inserted as described. This arrangement insures to an office protection against duplicate keys."

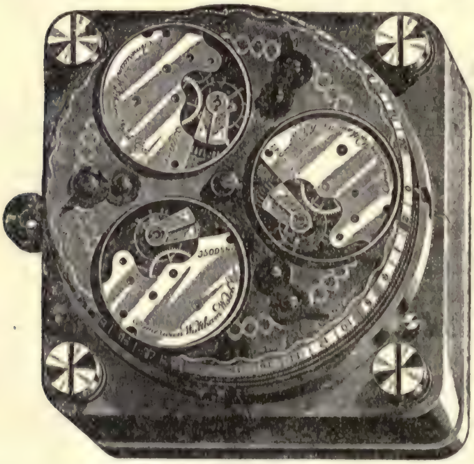


FIG. 9.—Yale time-lock.

Time and Bank Locks.—Recent improvements in Yale time-locks include an entire rearrangement of parts and introduction of the triple movement, or, by duplication of parts, the sextuple movement, thus avoiding the risk of "locking out." One form of triple movement is shown in Fig. 9, and it is arranged so as to be used in connection with the Yale automatic bolt-operating device, or a similar time-lock is adapted to be used for dogging or releasing the bolt-work of a combination-lock. These time-locks contain high-class watch-movements, and are now in extensive use. The Yale automatic bolt-operating device throws the bolt-work automatically at the time indicated by the time-locks, without requiring any external communication. This has been devised in order to avoid the use of spindles, or any working parts extending through the door, it having been found that the introduction of liquid explosives through the joint around the spindle constituted a vital point of attack. On the automatic bolt-operating device there is no external communication whatever, the bolt-work being thrown by springs upon the closing of the safe or vault door, and remaining locked until a second set of springs is released at any predetermined time by means of a time-lock such as shown above, thus unlocking the door. (See SAFES.)

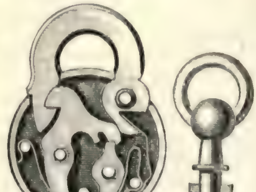


FIG. 10.—Ames padlock.

Padlocks.—A solid bronze spring padlock is manufactured by the Union Lock Co., in which the shackle does not draw out like a Scandinavian lock, but is hinged and fast on one end, while the opposite or free end is securely locked by a double bolt, making it impossible to be sprung open, or opened with anything but a key expressly made for each lock.

A padlock made by the Ames Sword Co., of Chicopee, Mass., and adopted by the United States Treasury for bonded cars and warehouses, is shown in Fig. 10. It is claimed to be non-pickable, and is made wholly of cast bronze. The key is double-bitted, turning indefinitely both ways.

Locomotive Condensation: see Engines, Steam Stationary Reciprocating.

Locomotive Crane: see Cranes.

LOCOMOTIVES. There are now used for passenger and freight traffic in the United States four principal types of locomotives: 1, the passenger or light-freight locomotive, which is designated the "American" type, having four coupled drivers and a four-wheel truck or bogie in front (see Vol. I, p. 304 *et seq.*); 2, engines for heavy passenger or fast-freight service, having six-coupled wheels with a leading four-wheeled truck, known as the "Ten-wheel" type; 3, those with six-coupled wheels and a pony-truck or single radiating pair of wheels in front, called the "Mogul" type; 4, heavy freight-engines, "Consolidation" type, having eight-coupled wheels and a pony-truck in front. Besides these, a great variety of types has been worked out to meet special conditions of service; as four-wheel and six-wheel switching-engines, without trucks, and with tank and fuel carried on the engine or on a separate tender. For elevated railroad service, light locomotives of the Forney type are used, with four-coupled wheels under the engine, and a four-wheel rear truck carrying the water-tank and fuel. For local or suburban passenger-trains, four-coupled engines are employed, having a two-wheel truck front and rear, or a two-wheel truck front and a four-wheel truck at the rear. Decapod or ten-coupled engines have been constructed to some extent for heavy freight service on steep gradients. The accompanying table gives dimensions, weights, and weights of trains, for some of the types of American locomotives constructed by the Baldwin Locomotive Works.

Each of the types named in the table is constructed of several sizes. Of the principal types two examples are given: (1), the average used on the greater mileage of lightly built roads, and (2) the heaviest which has come into use on railways of maximum traffic. The form of boiler in general use for bituminous coal-burning engines of the American "Ten-wheel" and "Mogul" types, is one with a deep fire-box placed between the rear driving-axle and the one preceding it. For burning anthracite a larger fire-box is required, which is made shallower, and extended over the rear driving-axle. The larger grade area necessary in the larger bituminous engines, now coming into general use, has led to the adoption of the same arrangement. Locomotives of the "American" type, and frequently the "Mogul" and "Ten-wheel" types, are usually constructed with boilers of the wagon-top pattern—that is, with the outer shell elevated and enlarged over the frames to give increased steam-space, and to increase the weight on the driving-wheels. The crown-sheets of the furnaces are supported either by crown-bars placed transversely and supported at their ends on the side sheets, or by radial stay-bolts tapped through the crown-sheet and roof of the boiler and riveted over. The latter construction is coming largely into use in connection with the wagon-top form, the dome being located on the wagon-top portion, which is extended in front of the furnace to receive it. Crown-bars placed longitudinally are unusual.

In the United States all locomotives for road service, as distinguished from switching and pushing engines, have leading trucks. Not only do American engineers depend upon the truck to guide the engine safely, at fast speed, around curves of short radius, but the ability of the locomotives to traverse such curves has had its natural effect upon the construction of the roadway. Curves are employed which would be impracticable but for the flexibility of the locomotives, and the cost of construction is correspondingly reduced. The trucks are either two-wheeled or four-wheeled. The two-wheeled trucks invariably have a swinging bolster and radius-bar. Radial axle-boxes are rarely used. Four-wheeled trucks are always center-bearing and swiveling, and are either with or without a swinging bolster to give lateral motion. To facilitate traversing curves, it is usual to omit the flanges from either the intermediate or leading coupled wheels. In the "Mogul" and "Consolidation" types the front and back pairs of coupled wheels have flanges, while the intermediate wheels are without flanges. In the "Ten-wheel" type the leading and trailing coupled wheels can be flanged, the intermediate wheels plain, and the truck or bogie made with a swinging bolster; or the middle and back pairs flanged, the front pair plain, and the truck without swing motion. The first method is considered better for roads having sharp curvatures, but the second is preferred by many, and answers satisfactorily on straight roads or those having only easy curvature.

Referring to the table, Nos. 1, 3, and 5 are the classes most widely used for passenger and freight service on light lines, laid with rails weighing from 50 to 60 lbs. per yd. No. 2, express passenger engine, is the type at present in use on the fastest trains between New York and Washington, and represents the most approved practice in high-speed locomotives. No. 4, heavy "Ten-wheel" locomotives, are used for passenger service on the long severe grades of the Baltimore and Ohio Railroad, for heavy fast-freight service on the New York, Lake Erie and Western Railroad, and for both passenger and freight service on other lines. The full-page illustration shows a compound engine of this class on the New York, Lake Erie and Western Railroad. No. 6, "Consolidation" type, has been generally adopted for heavy-freight service, and especially for the haulage of coal, iron-ore, and other heavy materials.

Table showing Dimensions, Weights, etc., of American Locomotives, 4 ft. 8 in. gauge.

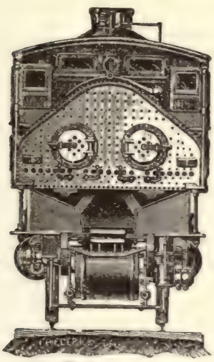
Designation and type of locomotive.	Disposition of wheels.	Cylinder's diameter × stroke.	Driving-wheels.	Wheel-base. Driving.	Wheel-base. Total.	Weight of engine in working order. On driving-wheels, lbs.	Weight of engine in working order. Total lbs.	Weight of engine in working order. Engine and tender.	Reputed weight of train. Level.	Reputed weight of train. 1 in 100.	Reputed weight of train. 1 in 50.	Reputed weight of train. 1 in 33.
			In.	Ft. In.	Ft. In.				Tons.	Tons.	Tons.	Tons.
1. Ordinary passenger, American type.	4-coupled wheels with 4-wheel truck	17 × 24	56 to 66	8 6	22 6	50,000	80,000	136,000	1,330	305	145	80
2. Express passenger, American type.	Ditto	20 × 24	72 to 78	7 6	21 11	75,000	116,000	188,000	2,000	470	230	135
3. Ordinary freight and mixed traffic, ten-wheel type.	6-coupled wheels with 4-wheel truck	18 × 24	56	13 6	23 7	68,000	92,000	152,000	1,825	435	220	130
4. Fast freight or heavy passenger traffic, ten-wheel type.	Ditto	21 × 26	62 to 68	12 6	23 4	101,000	133,000	205,000	2,725	655	335	200
5. Ordinary freight, Mogul type	6-coupled wheels with leading radial pony-truck	18 × 24	50 to 56	15 0	22 6	74,000	90,000	150,000	1,995	480	245	145
6. Ordinary freight, consolidation type.	8-coupled wheels with leading radial pony-truck	20 × 24	50	14 0	21 6	104,000	118,000	184,000	2,820	685	355	220
7. Heavy freight, consolidation type.	Ditto	22 × 28	50	14 0	21 6	135,000	150,000	222,000	3,670	900	465	290
8. Heavy freight, decapod type	10-coupled wheels, with leading radial pony-truck	22 × 26	45	17 0	24 4	135,000	150,000	222,000	3,670	900	465	290
9. Light switching	4-coupled wheels, saddle-tank	15 × 24	44	7 0	7 0	60,000	60,000	......	1,580	400	215	140
10. Ordinary switching	6-coupled wheels, 8-wheel tender	18 × 24	50	10 6	10 6	78,000	78,000	126,000	2,120	520	270	170
11. Heavy switching	Ditto	20 × 24	50	11 0	11 0	100,000	100,000	160,000	2,715	670	350	220
12. Elevated service, Forney type.	4-coupled wheels and trailing truck	12 × 16	42	5 0	16 1	32,000	47,000	......	865	215	100	60
13. Local or suburban service, double-ender type.	4-coupled wheels, pony-truck, and trailing truck	17 × 24	56 to 62	7 6	32 0	62,000	124,000	......	1,650	405	205	125

Having four pairs of driving-wheels not only is the greater part of the total weight utilized for adhesion, but the weight is so distributed as to bring a less load per axle than in either the "Mogul" or "American" types. With driving-wheels not exceeding 50 in. diameter, the length of driving-wheel base is such as to permit passing any ordinary curves, say up to 15°, or 382 ft. radius, with ease. No. 7, heavy Consolidation type, is the development of the ordinary Consolidation engine to meet the necessity for a powerful locomotive for freight and pushing service on mountain lines, inclines, etc. It is the resultant of the adoption of the same loads per axle for Consolidation engines as have been found practicable with American, Mogul, and Ten-wheel engines, the diameter and spread of driving-wheels remaining unchanged. In many locations, where pushing-engines are employed, it is practicable to lay heavier rails, and, if necessary, to specially strengthen the bridges for such distance as may be required. If, however, the distributed weight of such an engine is greater than the rails or bridges can safely carry, the same aggregate weight can be divided among five pairs of driving-wheels, making an engine of the Decapod type, the dimensions of which are given by No. 8. Although a wheel-base of 17 ft. is necessary for the five pairs of driving-wheels, the passage of curves is facilitated by allowing extra play between the track and the flanges of the rear pair of coupled wheels. The rigid wheel-base is thus virtually reduced to 12 ft. 8 in., and curves of 330 ft. radius may be safely traversed. No. 9 is a light switching locomotive. It is of the simplest type possible, the fuel and water being carried on the machine itself, and all the weight, being on the driving-wheels, is utilized for adhesion. It is therefore extremely powerful for its aggregate weight. Its short wheel-base permits it to enter with ease the sharpest curves in switches and side-tracks. Such engines are built of all sizes, from 7 × 12 cylinders and 7 tons weight to 17 × 24 cylinders and 35 tons weight, and are extensively employed for handling cars at railway termini, on docks, and around furnaces, mills, mines, and other industrial establishments. For service where greater tank and fuel space is necessary than can be provided on the engine itself, a separate tender carried on four or eight wheels can be used instead of the saddle-tank. Engines for similar service are constructed with three pairs of driving-wheels, when the weight of the engine or of the rails renders it inexpedient to concentrate it on two pairs.

Such engines are referred to by Nos. 10 and 11 in the table. The heavy switching-engines used by the principal railway lines are usually of this pattern, with eight-wheel tender and wedge-shape or sloping-top tank. This peculiar form of tank is adopted for two reasons, viz., to enable the engine-men to have a better view of the track and cars when backing and coupling, and to enable the trainmen more conveniently to climb over the tender. Switching-engines are now generally made of sufficient power to handle as great a weight of train as the freight locomotives can bring in. They must therefore have as much weight on the driving-wheels as the heaviest road-engines. No. 12 is the pattern generally adopted for elevated railroad service in New York, Brooklyn, and other cities; also for light passenger-service on short suburban surface-roads. In many of the larger cities, notably Chicago, where heavy suburban service on the surface railways requires special engines of great power, locomotives are employed of the type referred to by No. 13. They are built with four and six wheels coupled, and frequently with cylinders as large as 18 × 24.

Locomotive-Boiler Construction.—The general features of the boiler do not differ from those shown in Vol. I of this work. That part of the boiler over the furnace is enlarged by what is termed the wagon-top, for two purposes, viz., to give greater steam-space, and to increase the weight on the driving-wheels. The furnace and outer shell are made of mild steel, the usual requirements being a tensile strength of as nearly as possible 55,000 to 65,000 lbs., elongation 30 per cent in section 2 in. long, and phosphorus not exceeding ·03 for fire-box plates, and ·05 for the plates of the outer shell. The tubes are of lap-welded iron, usually No. 13 Birmingham wire-gauge, but frequently No. 12 or 11, rolled in the tube-plates and beaded over. The ends in the fire-box tube-plate are swaged down to allow for a copper ring or liner, which acts as a gasket or cushion between the tube and the plate, rendering the tubes less liable to leak under variations of temperature. The fire-door opening is formed by flanging and riveting together the inner and outer sheets. A conspicuous difference between English and American boiler construction is the absence in the latter of angle-irons for joining the parts: thus, the smoke-box tube-plate is made circular in form, flanged and riveted into the cylindrical waist of the boiler. The usual working steam-pressure is from 135 to 150 lbs. per sq. in., but recently a number of railways have sought greater efficiency and economy by adopting pressures of from 160 to 180 lbs.

The development of higher pressures, and the difficulty of overcoming trouble by the breaking of the side stay-bolts near the top of the furnace, have led to the adoption by many of a construction in which the fire-box crown is arched, and supported by radial stay-bolts tapped through the crown-sheet and roof of boiler and riveted over. The arched form of crown-sheet allows the sediment to drain off without obstruction. By entering the boiler through the dome the entire crown is easily accessible for removing scale. It is therefore especially suitable for locations where impure water must be used. The removal of the weight of the crown-bars permits the heating-surfaces to be increased without exceeding a fixed limit. The gradual lengthening of the stays from the short ones supporting the side-sheets to the long ones supporting the crown, prevents distortion by concentration of strain at a particular point, and therefore overcomes the breakage of bolts, which is frequent in boilers of the crown-bar or Belpaire patterns, designed to carry high pressures, unless constant vigilance is exercised. (For the above description of American types of locomotives we are indebted to D. K. Clark's work on the *Steam-Engine* edition of 1892.)



End view.

The Wootten Locomotive Boiler (shown in Fig. 1) is the invention of Mr John E. Wootten, and is the subject of six United States letters-patent, granted from 1877 to 1887. It has been largely adopted in the Philadelphia and Reading and other railroads using anthracite coal. The distinguishing features of the Wootten locomotive as

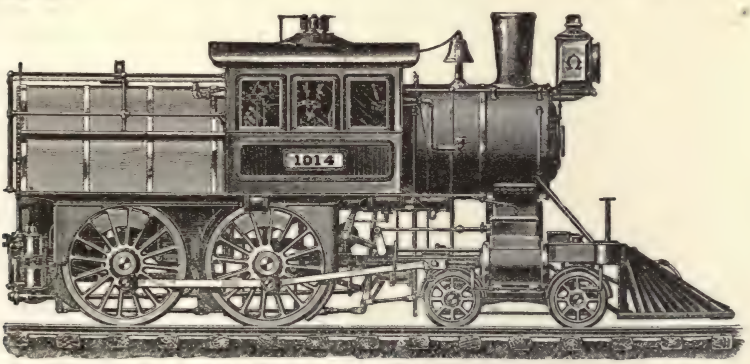


FIG. 1.—Wootten locomotive boiler—elevation.

compared with others, is a much greater breadth of furnace and larger area of grate with less depth of fuel thereon, a change in the location of the cab from the rear of the engine and at the sides of the fire-box to a position above the furnace in some instances, and in others on each side of the waist of the boiler immediately in front of the fire-box, the steam-dome being located in the cab. The construction of frames, driving-wheels, cylinders, and steam-chests is not strikingly different from other well-known and usual types of engines. The constantly increasing weight of train-loads has necessitated more powerful engines; and while it was not difficult to increase the cylinder capacity or piston displacement of the engines, the limit of the boiler to supply adequate steam to such engines was soon reached. The gauge of the railroad appeared to limit the width of the boilers admissible, the frames could not be spread any farther apart, and, under the practice of placing the furnace of the boiler between the frames, the only increase of grate-surface practicable was in the direction of length. This rendered firing more difficult, and a deep bed of fuel was required to maintain steam-pressure; the draft of air to maintain combustion demanded greater pressure on the exhaust, which could only be enforced by contracting the nozzle of the exhaust-pipe, and imposing a pressure upon the steam-pistons during the return strokes. This, in view of the large piston-surface recently coming into vogue, especially in compound locomotives, means a serious waste of force. The solution of this difficulty was found in an increased breadth of furnace-grate and fire-box to accommodate it. Space to contain such boilers without interfering with the driving-wheels was procured by placing the boiler above the driving-wheels and frames, which were protected from ashes by a hopper-shaped ash-pit. A report of series of tests made by Dr. Charles M. Cresson of the Standard locomotive boiler of the Baldwin Locomotive Works, and of a Wootten boiler burning several kinds of fuel, which shows the claims for the capacity of the Wootten boiler as an efficient steam generator with different varieties of fuel, including some incapable of use in ordinary locomotives, to be fully sustained, is quoted as follows by a committee of the Franklin Institute (see *Jour. Frank. Inst.*, September, 1891):

	Total heat units in fuel used.	Heat units utilized in generating steam.	Equivalent lbs. of water evaporated from 212° F.	Per cent of total heat utilized.	
Anthracite waste..........	11,275	7,823	8·09	69·4	Freight consolidation, Wootten.
" marketable....	11,913	7,813	8·08	65·5	Passenger, Wootten boiler.
" "	11,275	5,647	5·84	50	" ordinary boiler.
Bituminous waste..........	12,764	8,209	8·49	64·3	Freight consolidation, Wootten boiler.
" marketable...	13,402	9,302	9·62	69·4	" " " "
" " ...	13,402	7,397	7·65	55·2	" " ordinary boiler.
" " ...	13,363	9,138	9·45	68·3	Passenger, Wootten boiler.
" " ...	13,731	7,416	7·67	54	" ordinary boiler.
Lignite, 20 per cent water.	7,871	3,316	3·43	42·1	Freight consolidation, Wootten boiler.

For 18 × 24 to 20 × 24 road locomotives with the Wootten boiler, a grate-surface of 76 sq. ft. is obtained, the length of the grate being 9½ ft. and its width 8 ft. Between the grates and the tube-plate, and separated from the first by a fire-brick bridge wall, is a combustion-chamber about 3 ft. long, which is set into the cylindrical part of the boiler, and correspondingly shortens the tubes. By adopting so large a grate-area is obtained a low velocity of air passing through the fuel, and a slowness of combustion, which are of the utmost value in burning fuel too light to remain on the grates of ordinary locomotives, or impure fuel requiring the combustion of a large volume to produce sufficient heat. This type of boiler has been adopted by many of the railways in the anthracite coal regions, which are not only carriers but producers of anthracite coal, and must therefore utilize the cheap grades in order to market the more valuable grades, a fixed proportion of both attending the production. Separate cabs are provided for the engineer and fireman, as the former is preferably located in front of the fire-box, while the latter must stand on the tender.

Compound Locomotives.—During the past three years much attention has been given to developing and perfecting compound locomotives. They have been the subject of numerous patents, which may be divided into four classes, viz.:

1. Those with concentric cylinders, the high-pressure cylinder inclosed in the low-pressure cylinder, of which the most important example is the design of Mr. F. W. Johnstone, Superintendent of Motive-Power of the Mexican Central Railway, of which a number of engines have been constructed by the Rhode Island Locomotive Works, of Providence, R. I.

2. Those with cylinders placed tandem, the high-pressure cylinder being usually in front of the low-pressure cylinder. Engines of this type at this time (December, 1891) appear not to have passed the experimental stage. An important objection is the necessary length of the steam-ports connecting the two cylinders.

3. Those having two unequal cylinders, located one on each side of the engine, and exhausting from the smaller or low-pressure cylinder into a receiver exposed to the heated products of combustion in the smoke-box. The original patent covering this system was granted in 1873 to Mr. W. S. Hudson, late Superintendent of the Rogers Locomotive Works, of Paterson, N. J. This system has been further developed by Worsdell, Von Borries, Lapage, Lindner, and Mallet, in Europe, and by Pitkin, Dean, Lythgoe, and others in the United States.

4. Those having four cylinders, of which one high-pressure and one low-pressure cylinder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are placed on each side of the engine, the steam passing from one to the other by continuous expansion, without passing through a receiver. This system, which is the invention of Samuel M. Vauclain, Superintendent of the Baldwin Locomotive Works, has thus far been more extensively adopted than any other in the United States, about 150 locomotives having been constructed in the two and a half years following the date of the patent, June 25, 1889.

The general appearance of a recent Ten-wheel freight compound locomotive is shown in the full-page illustration.

The valve is of the type known as piston-valve, consisting of a hollow plug with cylindric rings at proper intervals, fitting into a cast-iron bushing, with apertures registering with the rim of the plugs, and leading to and from the ends of the cylinders, from the steam-pipe and to the exhaust-pipe. The movement of the steam from the steam-pipes through the steam-chest, high-pressure cylinder, piston-valve, low-pressure cylinder, and out at the final exhaust-port, is shown by the diagram Fig. 2. Fig. 3 shows an external view of the cylinders and steam-chest. The arrangement of the cylinders is immaterial; in locomotives with small driving-wheels, the large or low-pressure cylinder may be placed over the small or high-pressure cylinder, in order to obtain more clearance from the track. The following advantages were discovered in this type of compound locomotives by the Committee of Sciences and Arts of the Franklin Institute, which caused it to be awarded a gold medal:

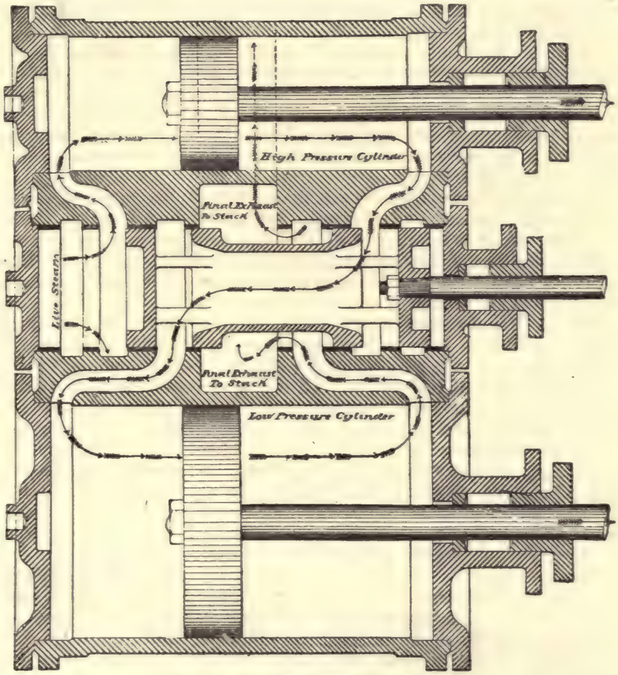

FIG. 2.—Section through cylinder.

"It can be applied to locomotives having outside cylinders, without increasing the entire

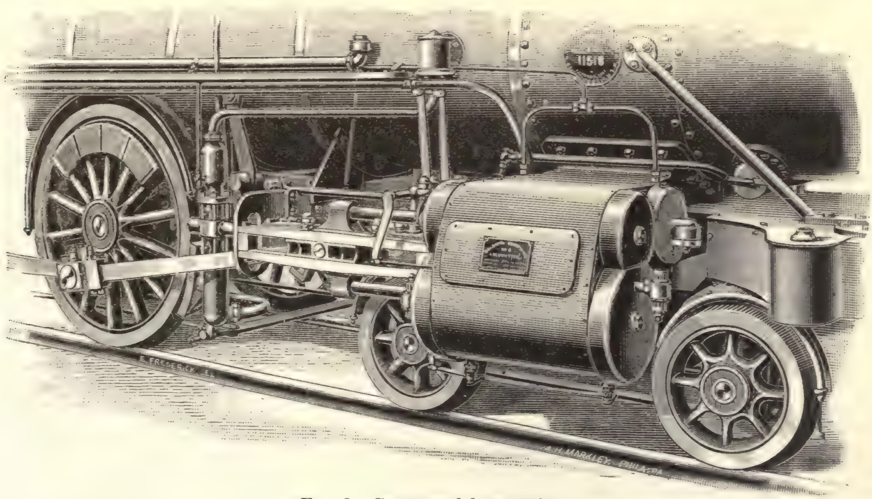

FIG. 3.—Compound locomotive.

breadth of the engines at the cylinders beyond the restrictions made necessary by bridges, tunnels, and trains upon parallel tracks. The transfer of steam from the low to the high

pressure cylinder is effected by the shortest possible conduit. The valve construction is simple, and, being balanced, requires a minimum of force to work it, irrespective of the steam-pressure upon it. The distribution of force upon each side of the engine is equal. Each side of the engine is capable of working when the other is disconnected, and when so operated can produce a draft sufficient to maintain effective steam generation for running purposes—a feature of decided importance in cases of accident disabling the engine on one side. The engine always starts promptly and steams readily with the diminished exhaust-pressure, the volumes of the exhaust being greater than with the Standard or non-compound engine, and occurring twice as often in the revolution of the shaft as in either the Webb or Hudson type of engine. It is not pretended that this compound engine imparts any new properties to the steam that is used in it, so as to surpass other well-proportioned compound engines in degree of expansion, and consequent economy of steam, but that it does diminish the clearance space between the high and low pressure pistons, and promptly proceeds with the expansion in the low-pressure cylinder, while in other types of engines the exhaust from the high-pressure cylinder must be retained in a receiver to await the opening of the valve admitting it to the low-pressure cylinder."

A number of tests have been made, with much care and accuracy. The results justify the conclusions reached by the committee, and show a gratifying economy of fuel.

Dimensions of a Compound Locomotive.—An express engine built by the Baldwin Locomotive Works for the Philadelphia and Reading Railroad combines the Wootten boiler and the Vauclain four-cylinder compound system. It has a two-wheel or Bissell leading-truck, four driving-wheels 6 ft. 6 in. diameter, and a pair of small trailing-wheels under the Wootten fire-box. The leading dimensions and particulars of the engine are as follows: Cylinders, high-pressure, 13 × 24 in.; low-pressure, 22 × 24 in. Diameter of driving-wheels, 6 ft. 6 in.; of truck-wheels, 4 ft.; of boiler, 4 ft. 9½ in. Form of boiler, straight; fire-box, Wootten patent. Size of fire-box, 114 × 96½ in. Number of tubes, 324; diameter, 1½ in.; length, 10 ft. Heating-surface, fire-box and combustion-chamber, 173·46 sq. ft.; tubes, 1,267·75 sq. ft.; total heating-surface, 1,435·21 sq. ft. Grate area, 76·00 sq. ft. Boiler-pressure, 175 lbs. per sq. in. Driving-wheel-base, 6 ft. 10 in.; rigid wheel-base, 13 ft. 10 in.; total wheel-base, 23 ft. 1 in. Weight on driving-wheels, (about) 76,000 lbs.; on leading truck, (about) 19,000 lbs.; on trailing, (about) 25,000 lbs.; total weight, (about) 120,000 lbs. Weight of tender, loaded, (about) 92,000 lbs. Diameter of tender truck-wheels, 2 ft. 9 in. Coal capacity of tender, 5½ tons. Water capacity of tender, 4,000 gal. Brake-fitting, Westinghouse automatic.

Comparative Tests of a Standard Consolidation and a Compound Consolidation Locomotive.—Tests were made in August and September, 1891, by A. Vail, General Master Mechanic of the New York and Pennsylvania Railroad, of two engines built by the Baldwin Locomotive Works, of the Consolidation pattern, duplicates of each other as far as possible, except that one was a standard engine and the other was a compound. The following is a summary of the results of all the tests, viz., two round trips of the standard engine and three round trips of the compound:

ENGINE.			Weight of train in lbs.	Average weight on train.	Time on road.	Actual running time.	Time throttle was open.	Lbs. coal used.	Lbs. water used.	Lbs. train hauled per lb. of coal.	Lbs. water evaporated per lb. of coal.	Average steam-pressure.
					H. M.	H. M.	H. M.					
Standard...	Two round trips.	South.	1,781,410	3,530,671	21 51	16 38	14 29	28,800	181,790	122·6	6·31	147·7
		North.	4,279,933									
Compound.	Three round trips.	South.	3,177,125	5,769,628	34 57	24 25	......	30,010	230,850	192·2	7·69	166
		North.	8,362,131									

Percentage of train hauled per lb. of coal, favor of compound, 36·2 per cent. Percentage of water evaporated per lb. of coal, favor of compound, 17·9 per cent.

The Webb Compound Locomotive.—Before deciding definitely on the use of compound locomotives, the Pennsylvania Railroad Co., in 1889, imported from England a locomotive made by Beyer, Peacock & Co., of Manchester, from designs and specifications of F. W. Webb, Chief Engineer and Superintendent of the London and Northwestern Railway. This locomotive was thoroughly experimented with for over a year, during which time changes were made in its running-gear, to adapt it to the requirements of an American track. The results of the experiments showed a saving of fuel over the ordinary engine of from 20 to 25 per cent. Fig. 4 represents the engine as altered. The boiler is 50 in. in diameter, straight, with copper fire-box 66 in. long, which is built with water-space below the grates and across the bottom, thereby forming an ash-pan surrounded by water A brick arch is used in the fire-box. There are four driving-wheels 6 ft. 3 in. diameter, and a pair of leading-wheels, which take the place of the American four-wheel truck. These wheels are fitted with radial boxes, which allow the engine to curve easily, which is proved by the flanges not showing any perceptible wear. The driving-wheels are not connected by side-rods, and are equivalent to two single driver engines in one frame. The back pair is operated by two high-pressure cylinders, 14 × 24 in., which are coupled to crank-pins at an angle of 90°. The front drivers have a shaft with a crank in the center, for one cylinder. The low-pressure cylinder, 30 × 24 in., is located underneath the smoke-box, and is operated by exhaust steam from the two high-pressure cylinders when the engine is

doing its regular work. This arrangement allows either pair of drivers to slip without interfering with the other, and by this means the pressure in the receiver is always automatically adjusted. The valve motion is of the radial type. The maximum travel of the valve is 3½ in. on the high-pressure cylinders, with steam and exhaust-ports 10 in. long. The low-pressure valve travels 4$\frac{13}{16}$ in. at maximum amount, with ports 18 in. long. Steam is taken to the high-pressure cylinders through a 3-in. pipe to each steam-chest, and after doing its work there it is exhausted through two 5-in. pipes around the smoke-box to the low-pressure steam-chest. This receiver-pipe has a safety-valve which is set at 60 lbs., which prevents any excess of pressure accumulating in the low-pressure cylinder or steam-chest. There is a valve arranged in this receiver which is connected with the exhaust-pipe of the low-pressure cylinder, which is under control of the engineer, whereby he allows the exhaust from the high-pressure cylinder to pass out of the receiver to the low-pressure exhaust-pipe to the atmosphere, without going into the low-pressure cylinder. There is also another valve operated from the cab, that lets steam from the boiler direct into the low-pressure steam-chest. By these arrangements the high-pressure and the low-pressure engines are made independent of one another. The engine can also be run to a terminal with either two of the cylinders disabled—i. e., if both high-pressure cylinders are out of service. or one high-pressure and the low-pressure, or with either one of them.

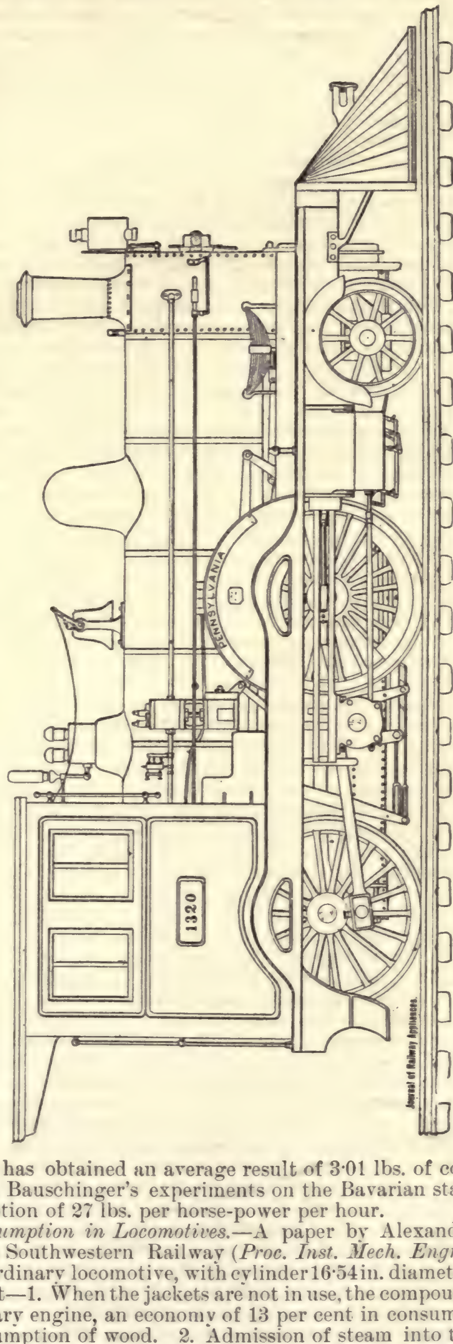

FIG. 4.—Webb compound locomotive.

This engine is also equipped with two separate valve-gears, which allow the working of steam at any point of cut-off desired in the high-pressure cylinders without interfering with the point of cut-off in the low-pressure, and *vice versa.* The exhaust-pipe is attached to each side of the low-pressure cylinder, and passes up above the steam-chest, where the two parts come together, forming one opening for the outlet.

Fuel Consumption of Locomotives.—Experiments by M. Georges Marie. of the Paris and Lyons Railway (see *Proc. Inst. Mech. Engrs.*, May, 1884), give the following results: Consumption of fuel per effective horse-power per hour, 3·27 lbs.; consumption of fuel per indicated horse-power per hour, 2·88 lbs.; ratio of consumption of water to consumption of fuel, 8·88 to 1; ratio of dry steam produced to fuel consumed, 8·08 to 1. M. Regray, of the Eastern Railway of France, has obtained an average result of 3·01 lbs. of coal per indicated horse-power per hour. Prof. Bauschinger's experiments on the Bavarian state railways showed an average water consumption of 27 lbs. per horse-power per hour.

Effect of Steam-Jackets on Steam Consumption in Locomotives.—A paper by Alexander Borodin, Engineer-in-Chief of the Russian Southwestern Railway (*Proc. Inst. Mech. Engrs.*, August, 1886) reports a series of tests on an ordinary locomotive, with cylinder 16·54 in. diameter, 23·62-in. stroke, from which he concludes that—1. When the jackets are not in use, the compound engine gives, in comparison with the ordinary engine, an economy of 13 per cent in consumption of steam, and of 24 per cent in consumption of wood. 2. Admission of steam into the jackets does not sensibly affect the consumption of steam in the ordinary engine; while in the compound engine it produces an injurious effect, increasing the consumption of water and wood per indicated horse-power.

Petroleum-Fuel in Locomotives.—Experiments by Thomas Urquhart, of Russia (*Proc. Inst. Mech. Engrs.*, August, 1884), show that an evaporation of 12·25 lbs. of water, at a pressure of 120

lbs. per sq. in., is obtained in practice from 1 lb. of petroleum refuse, while anthracite gives an evaporation of only 7 to 7½ lbs., showing that the practical evaporative power of petroleum is from 63 to 75 per cent higher than that of anthracite. Theoretically the petroleum refuse has only 33 per cent greater value than anthracite, but in burning the latter 40 per cent of its heating power is unavoidably lost, giving only 60 per cent efficiency, while in burning petroleum only 25 per cent is lost, giving 75 per cent efficiency. The petroleum refuse is the residue known as naphtha refuse, left after distilling from crude petroleum the kerosene, benzine, and other light products, and in Russia it amounts to from 70 to 75 per cent of the original weight of crude oil used. In Pennsylvania, the amount of illuminating oil obtained is from 70 to 75 per cent of the crude oil used. The composition of the Russian and the Pennsylvania oils is, however, nearly the same.

Mr. Urquhart used a steam spray-injector for forcing the liquid fuel into the furnace. His combustion-chamber was constructed with brick-work inside it, which when heated acted as a regenerator. Through the brick-work were made numerous channels or gas-passages. The brick-work thus offered a slight resistance to the free exit of the ignited gases, and so retained them longer in the combustion-chamber and fire-box, thus securing better admixture with the air, as well as a long circuit before they entered the tubes. The air carried in with the injector was pre-heated as hot as possible by being introduced through the forward ash-pan damper, and passing upward through a channel in the heated brick-work. Considerable advantage was thus obtained, and also by pre-heating the petroleum. A comparison of the consumption and cost of coal and of petroleum refuse per engine-mile in 8-wheel coupled 48-ton locomotives on the Grazi and Tsaritsin Railway gives the following average results:

Coal, 79·08 lbs. per engine-mile; cost, 11·02 pence per engine-mile.

Petroleum refuse, 40·47 lbs. per engine-mile; cost, 5·84 pence per engine-mile.

Numerous experiments with petroleum-fuel for locomotives have been made in the United States, with successful results, as far as the evaporative power of the fuel is concerned; but on account of the greater relative cheapness of coal as compared with petroleum in most locations in the United States, no commercial advantage has yet been found with oil fuel sufficient to justify its introduction in practice.

Locomotive Speed.—Mr. M. N. Forney, in a paper on this subject in *Scribner's Magazine*, March, 1892, discussing the prospect of a speed of 100 miles per hour being reached, concludes that there "is not much probability of attaining regular and continuous speeds of 100 miles per hour with our present locomotives. Their fire-boxes—which perform the same functions for the machines that their stomachs do for animals—are, with the present system of construction, necessarily contracted in size. The weight of the whole locomotive being fixed, the dimensions of the different parts are also limited. Fast running," in Mr. Forney's opinion, "is largely a question of steam production. Given a boiler which will generate enough steam, and the other problems are of comparatively easy solution. The difficulty is to get the boiler sufficiently large within the limits of size and weight to which it must be confined. It will be safe to say that to be able to travel continuously at 100 miles per hour we must have either boilers or fuel which will generate more steam in a given time than those we are using now do, or our engines must use less steam to do the same work; or, what is more probable still, we must have all three of these features combined. In the locomotive of the future, the action of the reciprocating parts will probably be more perfectly balanced than it is now; coupling-rods will either be dispensed with altogether, or their risk of breakage will be lessened by placing the driving-wheels near together; and both this danger and the disturbing effect of the reciprocating parts will be lessened by increasing the size of the wheels. To enable the engine—or, rather, its journals—to 'run cool,' the journals and their bearings will be increased in size so as to have ample surface to resist wear. In Mr. Webb's new engine, Greater Britain, recently built for the London and Northwestern Railway, the boiler has been materially increased in size, and he reports the remarkable performance of evaporating nearly 11 lbs. of water per lb. of coal while pulling a heavy train at the rate of over 44½ miles per hour. This engine is compounded so as to use steam with the greatest economy, and is without coupling-rods. These are dispensed with by using three cylinders—two high-pressure and one low-pressure. The two former are connected to the back pair of driving-wheels, and the latter to the front pair. By this means both pairs of wheels are driven by separate cylinders. A new express locomotive is now in process of construction in this country with a fire-box about twice as wide as those ordinarily used. The problem of improving the balancing of engines is attracting much attention, and the bearing surfaces of many recent locomotives have been materially increased. Driving-wheels have also been enlarged in size with the increase in speed."

Mr. Theodore N. Ely, in the same magazine, gives the following instances of notable train movements: The Pennsylvania locomotive which drew the special train of the delegates to the International American Conference on their tour to the principal cities east of the Rocky Mountains, traversed the rails of 20 distinct lines of railroad, and covered 10,000 miles in its course, without accident of any kind or unreasonable delay. Another example of endurance may be mentioned—the 126,000 miles made by one locomotive between Philadelphia and Washington in the year 1891—equal to five complete journeys around the world. Concerning the factor which will control the limit of speed in the passenger-trains of the future, Mr. Ely concludes as follows:

"In the road-bed we shall have to demand that the alignment be almost free from curvature, and the width between the tracks be increased; that the foundation shall be stable, and well protected from rain and frost; that land-slides and other accidental obstructions shall

be provided for; that the ties shall be firmly imbedded; that the rails shall be heavy—100 lbs., or more, if necessary—and securely fastened; that all frogs and switches shall be proof against accidental misplacement or rupture; that all draw-bridges shall be made secure beyond question; and, finally, that all crossings at grade be abolished. We must further insist that a thorough system of supervision and inspection shall be carried out. With a fulfillment of these conditions, which, professionally speaking, are perfectly practicable, trains, so far as the road-bed is concerned, may be run in safety as fast as any locomotive can be made to haul them. Of the locomotive it may be said, that only with the improvements in road-bed referred to can its highest attainable speed be utilized."

Mr. H. Walter Webb, of the New York Central and Hudson River Railroad, also in *Scribner's Magazine*, above noted, gives the following remarkable account of a fast run made by a locomotive and three large parlor-cars over the above-named railroad in September, 1891. The engine, hereafter described, weighed 100 tons. The aggregate weight of the cars, empty, over 130 tons. The journey from New York to East Buffalo, a distance of 436·32 miles, was made in 439·45 min. Allowing for time lost in changing engines at Albany and Syracuse, and for cooling a hot journal, the run of 436·32 miles was made in 426 min., or at the rate of 61·44 miles per hour. The most remarkable runs made before this were accomplished on the London and Northwestern and the Great Northern Railways of England. The distance over the former is 400 miles, and the run was made daily on a schedule calling for a speed of 53½ miles per hour. On the Great Northern the distance is 393 miles, and the schedule in this case called for a speed of 54 miles per hour. These trains were run daily for many weeks, and were generally punctual and within their schedule time. On several occasions, however, they exceeded the schedule, and made what at that time were regarded as phenomenal runs.

On August 13, 1888, the Northwestern train covered the distance of 400 miles in 427 min., or at a rate of 56⅛ miles per hour, and on August 31st the Great Northern train made the run of 393 miles in 412 min., or at the rate of 57¼ miles per hour. These individual runs were both remarkable, but the daily running of the trains on their published schedules were regarded by railroad men as still more extraordinary, and at that time there were no schedule trains in this country that approached them in point of speed. It must be remembered, however, that these English roads are possessed of many advantages not enjoyed by railroads in the United States, as, for instance, the long and numerous tangents, the entire absence of grade crossings, and, more especially, the light weight of the cars, 80 tons being the maximum weight of the trains used in the "race to Edinburgh." With equipment of the character required and used in this country, provided as it is with all luxuries, conveniences, and comforts, and a rate of two cents per mile, a train limited to the above weight could not carry a sufficient number of passengers to enable it to earn its running expenses.

Three years previous to these English records, a special train weighing 64 tons made a run on the West Shore Road from Buffalo to Weehawken in 9 hours and 23 min. In the published accounts different allowances for stops were made, making the average rate per mile vary from 51 to 54 miles per hour; either rate, however, making it the best long-distance run on record in the United States, until the run from New York to Buffalo over the New York Central and Hudson River Railroad, before noted. In this famous run a careful schedule of the running-time of each mile was kept, an analysis of which shows the following: 436 miles were run in 426 min.; 130 miles were run at a rate of less than 60 miles per hour; 118 miles were run at a rate varying from 60 to 65 miles per hour; 151 miles were run at a rate varying from 65 to 70 miles per hour; 37 miles were run at a rate varying from 70 to 78 miles per hour.

The problem presented to Mr. Buchanan, in designing the new type of passenger-engine now in use on the New York Central road for high-speed trains, was to obtain greater boiler capacity, greater adhesion, and greater tractive power. To obtain the desired increased boiler capacity and heating-surface, Mr. Buchanan located the fire-box, which formerly was between the sides or frames of the engine and between the axles of the driving-wheels on top of these frames and axles, and by so doing obtained an increase in the width of the fire-box of 5½ in., and an increase in its length of 25 in., being an equivalent of 9¾ sq. ft. of additional grate-area. The boiler-flues, which in the former engine numbered 238, he increased to 268, and by the change in the fire-box he was enabled to lengthen them 4½ in., thus obtaining an increased heating surface of 221½ sq. ft., the diameter of the boiler being increased from 51 to 58 in. With this increase in the grate-area and heating-surface the desired increase in boiler capacity was obtained. To secure the adhesion, the weight on the four drivers, which formerly was limited to 30 tons, was increased to over 40, or over 10 tons' weight on each driving-wheel. The old and lighter form of rail had already been removed, and replaced with the standard 80 pound section. To increase the tractive power of the engine the cylinders were enlarged 1 in. in diameter: being formerly 18×24, they were now made 19×24. All these changes had vastly increased the height and weight of the engine, and the criticism was freely made that its use would be destructive of roadway tracks and bridges. These objections, however, were more than met by original methods of suspending the engine on its springs. Formerly he springs were placed on top of the driving-boxes; in this case they were located beneath them, and connected with equalizing bars, thus allowing the use of a longer and more elastic spring than was formerly used; and it has been demonstrated that these engines are less destructive to road-bed and rail, are freer from the swaying motion usually found in engines hung from above the driving-boxes, and ride smoother and more comfortably than any in the service.

Of course, to obtain the speed that was sought, it was desirable to increase the diameter of the driving-wheels; but this was not done at first, nor until it was ascertained how successful had been the efforts to increase the boiler capacity of the engine. When it was found that this increase was ample, and even more successful than had been hoped for, the driving-wheels were changed, and the new ones of 6 ft. 6 in. in diameter, or 8 in. larger than the old ones, were attached. The gain in speed is most apparent, and can well be appreciated when it is remembered that the large driver makes 29·51 less revolutions in a mile than the small ones. On a trip from New York to Albany the decrease in the number of revolutions by the large 6 ft. 6 in. wheel would be 4,219·93, an equivalent of 86,154·09 ft., or a saving of nearly $16\frac{1}{4}$ miles. From New York to Buffalo the saving would be nearly $50\frac{1}{100}$ miles.

With a locomotive such as this for motive power, it is not a difficult matter to run profit-paying passenger-trains over long distances at a running rate of over a mile a minute; this, of course, assuming we have proper character of road-bed and rails, and approved appliances to insure safety and rapid speed.

LOGGER, STEAM. This name is given to a traction-machine devised by Mr. George T. Glover, which can be driven by steam over a snow road, and which, it is claimed, will draw after it from 30,000 to 40,000 ft. of logs. The machine is mounted on two sleds, midway between which the boiler is located. The boiler is of steel, $5\frac{1}{2}$ ft. in diameter, $7\frac{1}{2}$ ft. high, with 320 2-in. submerged flues, and gauged to a pressure of 150 lbs. The engine is 10 × 12 ft., and of double upright pattern. There are four wheels on the driving-axle, 4 ft. in diameter, weighing 3 tons. Each wheel is 1 ft. wide, and on its face there are 17 teeth, 9 in. apart. The angle of these teeth is 3 in.; they are held in place by bolts and nuts; therefore, if less traction-power is required, teeth of a shorter angle can be affixed. The axle of the drivers is of steel, 6 in. in diameter, 7 ft. long, and weighs half a ton. If desired, two of the wheels may be removed, and the remaining two placed on the axle in any position required. The steering-gear is simply a wheel in front, which places the tongue of the forward sled in any desired position by means of a link-belt chain running over the wheel, over pulleys attached to either side of the frame, and made fast to the sled-tongue. The drive-chain, between the engine and the drivers, is made of $1\frac{1}{4}$ in. Ulster iron, and weighs 18 lbs. to the ft. The logger is 28 ft. long, and, of course, a rigid machine of that size could not be driven over other than a level road. To overcome this difficulty, the drivers and the engine are supported by separate frames, the pivot-point of their connection being about the middle of the front sled. By unfastening the drive-chain and removing the connecting-bolts the two frames are disconnected, and the horse (the engine), as it were, may be taken from between what one might imagine to be the thills —the long timbers extending forward from the drivers. The bolts fastening the two frames together slide in slots; in the ends of the thills there are imbedded powerful springs, and to compress these springs to a proper tension are jack-screws, which are made fast to the engine-frame. It will thus be seen that the springs act as a cushion, and that the logger will adapt itself to the unevenness of a road. To further assist in this purpose there is a steam-piston, the upright box of which may be seen in the engraving over and immediately in front of the wheels. The piston-box is fastened to the frame of the wheels, and when necessary the rear sled, bearing the weight of the engine and part of the boiler, can be lifted clean from the ground by the use of the piston, thereby having but two points of contact, the front sled and the drivers, and at the same time throwing additional weight upon the latter. Increased traction of the driving-wheels is obtained by the use of exhaust-steam. The wheels are decked, and around the edges, under the frame, are heavy rubber curtains, which nearly reach to the road surface. The wheels thus work in a steam-box, are heated by steam, and when they pass over snow it is damped and compressed, and in cold weather immediately converted into solid ice. The machine weighs about 12 tons, and attains a speed of 5 miles per hour.

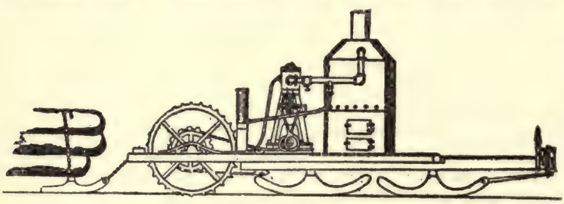

FIG. 1.—Steam logger.

Loop, Steam: see Steam-Loop.
Low Grinding: see Milling-Machines, Grain.
Machine-Gun: see Ordnance.
Magazine Rifle: see Fire-Arms.
Magnetic Separator: see Ore-Dressing Machinery.
Manganese Bronze: see Alloys.
Mankey, Woodwork: see Molding Wood-Machines.
Marine Engines: see Engines, Marine.

MEASURING INSTRUMENTS, ELECTRICAL. It needs no demonstration to show that accurate gauges for the measurement of electricity, especially when the same is used as a source of power or of light, are of as much importance as accurate steam-gauges for the measurement of steam. A gauge which will not measure the energy expended within 5 or 10 per cent, is simply blind to losses of equal magnitude in the cost of power. Up to within a comparatively few years, accurate electrical gauges did not exist outside of physical laboratories; and such instruments as were there employed were, from the very nature of their construction and the delicacy required in their handling, unfit for the comparatively rough usage

of the electric-lighting station. The need has been urgent for electrical gauges which are both simple and accurate—simple, in the sense that their mechanical parts should be few and easily adjusted ; accurate, in the sense that their operation should be certain, and the error so small as practically to be neglected.

A most important series of electrical measuring instruments, designed to meet these conditions, has been invented within the last four years by Mr. Edward Weston. It is impossible, within any space that can here be afforded, to describe all the many forms of entirely novel instruments which Mr. Weston has produced, and of which it may safely be stated that they are rapidly revolutionizing modern methods of practically measuring the electric current. Two of the principal forms are, however, illustrated in Figs. 1 to 4.

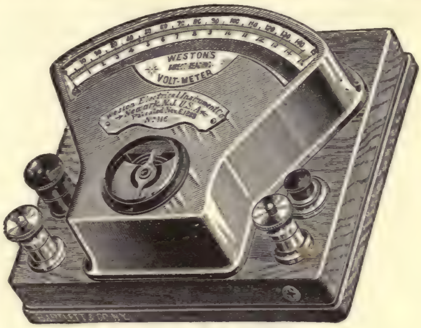

FIG. 1.—Volt and ammeter.

The Weston Direct Current Volt and Ammeter.—A perspective view of the exterior of this instrument is given in Fig. 1. The details of the mechanism will be clearly understood from Figs. 2 and 3. To the inner sides of the poles of a permanent magnet (Fig. 2) are secured cored-out pole-pieces. In the cylindrical space formed between these pole-pieces is supported a solid cylinder of magnetic material, by means of a brass bar bolted to the end of the magnet, and shown broken away in Fig. 2. This solid cylinder of magnetic material draws into itself the lines of force from the magnet-poles, so that in the annular space between the cylinder and pole-pieces an exceedingly intense field of force is produced. Surrounding the fixed cylinder is a coil of fine insulated wire, shown separately in Fig. 3. This coil is pivoted in caps, which are supported on the pole-piece. Volute springs similar to those used in watches are fastened to the core-pivots and to fixed abutments, and operate to oppose any movement of the coil upon its pivots. The index-needle is also supported on the coil-pivot, so that it moves, as shown in Fig. 1, over the scale.

The foregoing is practically all there is in the mechanism of one of the most accurate instruments ever contrived—so accurate, indeed, that in Mr. Weston's own laboratory it has displaced standard tangent galvanometers of the most costly construction. The current to be measured is by suitable electrical connections caused to traverse the spiral springs and the coil entering one spring, going through the coil and coming out at the other spring. When the coil is thus traversed by the current, there is produced about it a field of force which reacts upon the permanent magnet field. The coil is therefore, in accordance with well-known electrical laws, caused by the reaction of these two fields to turn on its pivots, and the extent of its angular motion is always dependent upon the difference of potential between the terminals of the instrument. If, then, the current be directed through a comparatively high resistance arranged in series with the coil, the apparatus becomes adapted for use as a voltmeter, or for measuring electrical pressure, and the scale is therefore graduated in volts. By varying the resistance the conditions in the instrument may be modified, so that it will measure from minute fractions of volts up to hundredths and thousandths.

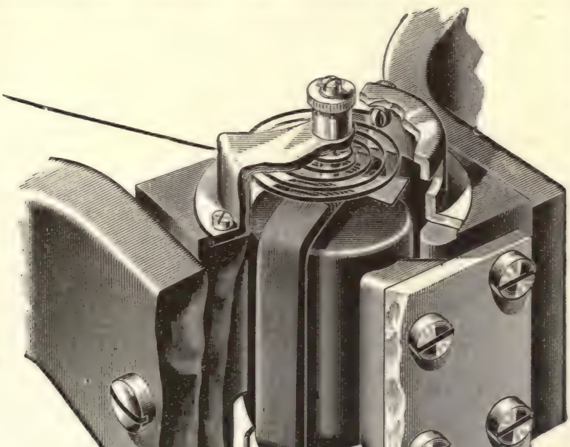

FIG. 2.—Weston electric gauge.

To the mechanic this instrument will be particularly interesting, because of the exceedingly ingenious joint, so to speak, which exists at the pivot of the coil. The problem here was to introduce the current into the coil without causing it to pass between moving surfaces, the relations of which might constantly change in conditions of wear, in which case the resistance to the coil at this point might be of unknown and variable quantity. Leading the current in through the springs, entirely overcomes any difficulty of this kind.

The Weston Alternating Current Voltmeter and Ammeter.—The difficulty of measuring a current which is rapidly alternating or reversing has always been recognized by electricians ;

especially when the need was understood of an index which should, despite these quick changes in the current, move steadily to its reading and there stand. Alternating currents have hitherto usually been measured indirectly, as by gauging the expansion of a fine wire heated by the current. The Weston instrument consists of a fixed coil held in suitable supports, within which is arranged a movable coil, the axis of the second coil being at right angles to that of the first. The movable coil and the support for the fixed coil

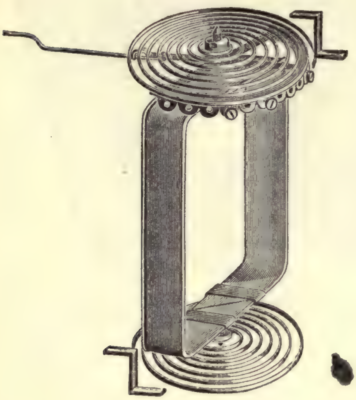

Fig. 3.

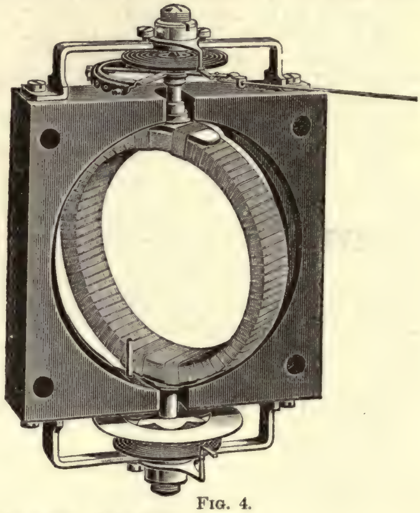

Fig. 4.

Figs. 3, 4.—Weston electric gauge—details.

(removed) are shown in Fig. 4. The movable coil has combined with it spiral springs arranged in substantially the same way as has already been described in connection with the direct-current instrument, and its pivot carries the index-needle, which moves over a scale similar to that shown in Fig. 1. The electrical connection of the two coils is such that the current to be measured passes through both of them, and therefore the field generated around the moving coil reacts upon the field generated around the fixed coil; and as a consequence the moving coil is caused to move over a distance bearing a relation to the difference of potential between the terminals of the instrument. Of course, changes in the polarity of the current equally affect both coils. If the current reverses in one, it also reverses in the other; so that, despite these reversals, the relation of one field to the other remains the same. Therefore, the movable coil simply traverses over the proper angular distance, depending upon variation in current pressure or current strength, and thus moves steadily up to its scale-marking, and stays there. The great sensitiveness as well as the simplicity of this instrument is remarkable. By suitable changes in the electrical connections, and the introduction of resistances, the instrument may be adapted either as a voltmeter or as an ammeter.

Among the other remarkable electrical measuring instruments devised by Mr. Weston, is an ammeter capable of measuring the strength of the whole current to be used by an electric-lighting plant. Instruments of this kind have been constructed capable of measuring over 15,000 ampères. He has also devised an entirely novel series of resistance coils.

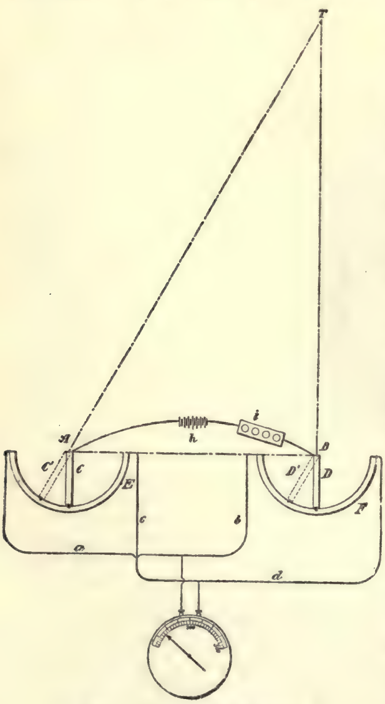

Fig. 5.—Fiske range-finder.

The Fiske Electrical Range-Finder.—This apparatus involves an entirely novel application of electricity to the measurement of distances at sea. It is the invention of Lieutenant Bradley A. Fiske, of the United States Navy, and its principle will be readily understood from the accompanying diagram (Fig. 5).

The apparatus proper consists simply of two arcs of conducting material, marked *E* and *F* on the diagram, which in reality are merely two lengths of wire supported on the circumference of two circular platforms resting on tripods. Centrally pivoted on each platform is an ordinary spy-glass or telescope, marked *C* and *D* in the diagram. Each telescope is provided with an arm or wiper, which sweeps over the wire or arc *E* or *F*, always making contact with it. The extremities of the arcs *E* and *F* are connected by wires *a b c d*, which are properly insulated and disposed between-decks, or in any way so that they will be protected from injury, just as are ordinary electric lighting or other wires. Connected to these wires is the indicating instrument, on the face of which there is a dial marked to indicate yards of range and a pivoted needle or pointer. With the pivots of the telescopes is connected a galvanic battery of any convenient form. This battery, with its conducting wires, may be placed below in the vessel in some protected position. The electrician will readily see from this diagram that the parts are connected in what is known as a Wheatstone bridge, or electrical balance circuit; and to him no further description will be necessary to explain the fact that when a balance occurs in the bridge the indicating instrument will show no deflection, and that when the balance is disturbed the deflection of the index will bear a relation to and practically measure the extent of the disturbance. Thus, for example, supposing the two telescopes to be placed in the positions *C* and *D*, the wiper on each then making contact with the central portion of each arc, then the resistance which the current will encounter in so much of its path as extends from the center of arc *E* to the ends thereof, and then through the wires *a* and *c* to the indicating instrument, will be equal to the resistance which it will encounter in the remainder of its path, measured from the central portion of arc *F* through wires *b* and *d* to the indicating instrument; and therefore the index will not be deflected. But if one of the telescopes—*C*, for example—be moved to the position *C′*, then the travel of the current through the greater part of the arc *E* and over the wire *c* will be over a longer path than when it travels over the less part of the arc *E* and the wire *a*; and, consequently, there will be a disturbance in the balance, which will be indicated by the movement of the needle of the index to a new position.

Now the telescopes are directed upon the object the distance of which is to be measured, and this object is marked at *T* in the diagram. It will be seen that the telescopes are, in fact, located at the extremities of a base-line *A B*, which may include the whole length of the vessel, or her entire breadth of beam. In the one case the two instruments would be located at the stern and on the forecastle, and in the other at opposite extremities of her bridge. Of course, the length of this base-line is known, and the distance *A T* is the range which is to be found out. Without going into the trigonometrical discussion involved, it will suffice to say that the distance *A T* depends upon the extent of the angle (*A T B*), which is included between the lines of sight of the two telescopes which are directed upon the object. If, then, one of these telescopes be moved from the position *C* to the position *C′*, for example, it will be evident that the angle included between the two positions of the telescope (*C C′*) will be equal to the angle *A T B*, and also will be measured by so much of the arc *E* as is included between these two positions of the telescope. But the change in position of the telescope, as has already been described, causes a disturbance of balance in the electrical circuit; and if the change in position of the telescope bears a relation to the range, as it does, then whatever measures the disturbance in the electrical circuit due to that change will equally measure the range; so that finally the range is shown by the extent of movement of the index-needle of the indicating instrument over its dial.

All that is done in practice is to station two observers at the two telescopes and cause them to direct their instruments upon the object. Then a third observer notes at once the range shown on the dial of the indicator. If the object moves, the two observers at the telescopes simply follow it with their instruments, and the needle of the indicator then moves as the range changes. Where the observers are separated by a considerable distance—as, for example, the entire length of a vessel—they may communicate with one another by an ingenious telephonic arrangement which is provided. The telephone transmitter and receiver are connected directly to the telescopes, so as to partake of their motion, and are so supported that the instrument talked into comes directly in front of the mouth of the observer, while the instrument at which he listens is held close to his ear. In this way one observer can tell to the other not only what object to look at, but upon what part of an object to direct his sight—often a very important matter when the presence of several objects may create confusion, or when the target or some portion of it is more or less obscured by smoke, or when the observers are screened from one another by deck structures.

The indicating instrument may be placed in any convenient position, and at any distance from the telescopes. There may be but one indicating instrument located, for example, at a given gun which is to be controlled, or any number of such instruments may be placed in the same circuit, when all of them will operate simultaneously to show the range.

MEASURING-INSTRUMENTS, MECHANICAL. *The Bellows Beam Micrometer* (Fig. 1) is a convenient instrument for mechanics desiring close measurements. The beam is provided with two heads—one fast, the other loose. The loose head is dovetailed to the beam, open on one side and flush with the face of the beam, and is provided with a micrometer-screw, having ½-in. adjustment Set in the face of the loose head on an angle of 10°, and held in place by a thumb-nut on the reverse side, is a hardened stop, which, being angular on its sides and having no bearing on its bottom, will adjust itself in position. The beam is divided in half-inches by the insertion of steel pins, and the loose head is quickly and accurately set by bringing the stop in its face to bear against them, and when set is held in

position by a locking-screw and nut, which acts like a gib. Fig. 2 is a section of the micrometer screw, nut, and fastening device.

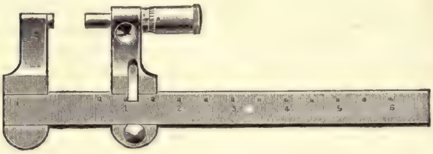

FIG. 1.—The Bellows micrometer.

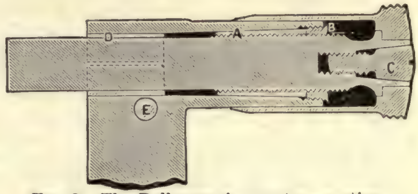

FIG. 2.—The Bellows micrometer—section.

Limit Gauges for Round Iron.—These gauges (Figs. 3 and 4) are the outgrowth of the efforts of the Master Car-Builders' Association to insure uniformity in the sizes of round

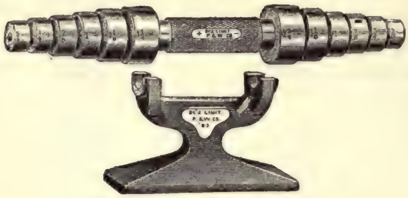

FIG. 3.—Round-iron gauge.

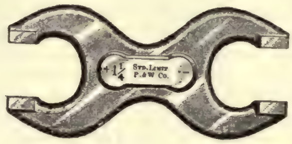

FIG. 4.—Round-iron gauge.

bar-iron for United States standard bolts. The following table of dimensions for limit gauges is recommended:

Size of iron.	Size of large end of gauge.	Size of small end of gauge.	Difference in size of large and of small diameter of iron.	Size of iron.	Size of large end of gauge.	Size of small end of gauge.	Difference in size of large and of small diameter of iron.
$\frac{1}{4}$ in.	0·2550	0·2450	0·010	$\frac{5}{8}$ in.	0·6330	0·6170	0·016
$\frac{5}{16}$ "	0·3180	0·3070	0·011	$\frac{3}{4}$ "	0·7585	0·7415	0·017
$\frac{3}{8}$ "	0·3810	0·3690	0·012	$\frac{7}{8}$ "	0·8840	0·8660	0·018
$\frac{7}{16}$ "	0·4440	0·4310	0·013	1 "	1·0095	0·9905	0·019
$\frac{1}{2}$ "	0·5070	0·4930	0·014	$1\frac{1}{8}$ "	1·1350	1·1150	0·020
$\frac{9}{16}$ "	0·5700	0·5550	0·015	$1\frac{1}{4}$ "	1·2605	1·2395	0·021

The caliper gauges are drop-forged from tool-steel, and are hardened and ground exact to size. Accompanying each set is a standard cylindrical reference gauge, hardened and ground, for each separate end

Measuring-Machines.—The Pratt & Whitney 12-in. standard measuring-machine is shown in Fig. 5. The screw is 50 threads per in., and has adjustments for compensation for wear in nut and shoulders. The index-circle is graduated to 400 divisions, giving subdivisions of $\frac{1}{20000}$ of an in.; while, by estimation, this may be further subdivided to indicate one half or even one fourth this amount. Delicacy of contact between the measuring-faces is obtained by the use of auxiliary jaws holding a small cylindrical gauge by the pressure of a light helical spring, which operates the sliding spindle, to which one of these auxiliary jaws are attached. The behavior of this "sensitive piece" readily determines the uniformity of contact of the measuring-faces at zero, and upon the gauge which is measured between them. An adjusting device for the index-line is provided, to allow for slight variations of position of the measuring-faces at zero, or for any convenient reading on the index-circle.

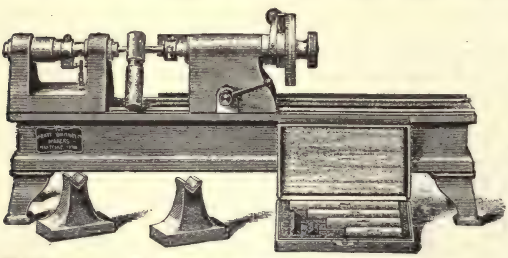

FIG. 5.—Measuring-machine.

Fig. 6 shows a measuring-machine made by the Gilkerson Machine Works, of Homer, N. Y. The screw has 16 threads to the in., and the wheel is graduated to read to $\frac{1}{10000}$ in. by decimals, and also $\frac{1}{32}$, $\frac{1}{64}$, etc. The error of the screw is corrected by means of an adjustable piece fastened to the bed of the machine. The arm shown travels with the wheel, the lower end bearing against the correcting piece being held in contact by gravity. The upper end, projecting forward, has a face on which may be graduated a vernier.

The Rogers-Bond Comparator.—From a lecture delivered at the Franklin Institute in 1884 by Mr. George M. Bond, the head of the gauge department of the Pratt & Whitney Co., who was associated with Prof. Rogers in the design and construction of the comparator, we abstract the following description: "The special features of the universal comparator are, as its name

implies, the variety of the methods employed and the range of work that can be done in comparing standards; each independent method, when carefully carried out, producing similar results, which serve to check or prove the comparisons. It includes a method for investigating the subdivisions of the standard by comparing each part of the total length with a constant or invariable quantity or distance."

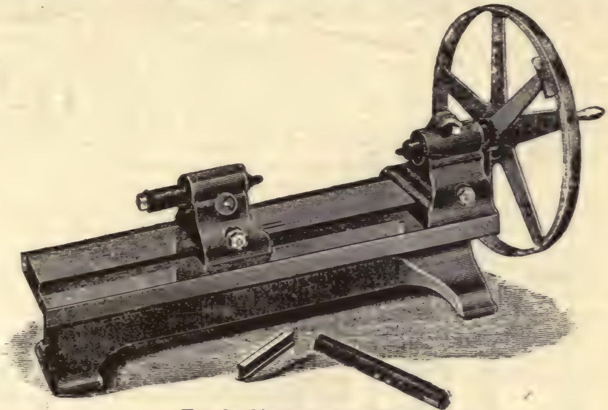

Fig. 6.—Measuring-machine.

Referring to the illustrations (Figs. 7, 8, 9), the main features of its construction are the following: "A heavy cast-iron base, *A*, is mounted upon stone-capped brick piers, giving a permanent foundation to the apparatus. Upon this base, and reaching from end to end, are two heavy steel tubes, *B* and *C*, 3 in. in diameter, ground perfectly straight, and being 'true' when placed in the centers of a lathe, the object being to get a straight-line motion of the microscope-plate *D*, which slides freely on these true cylinders. Flexure of these cylindrical guides is overcome by lever-supports at the neutral points n and n^1. Fitted closely to these guides and outside of the range of motion of the microscope-plate *D* are two stops, *E* and *F*, one at each end, as

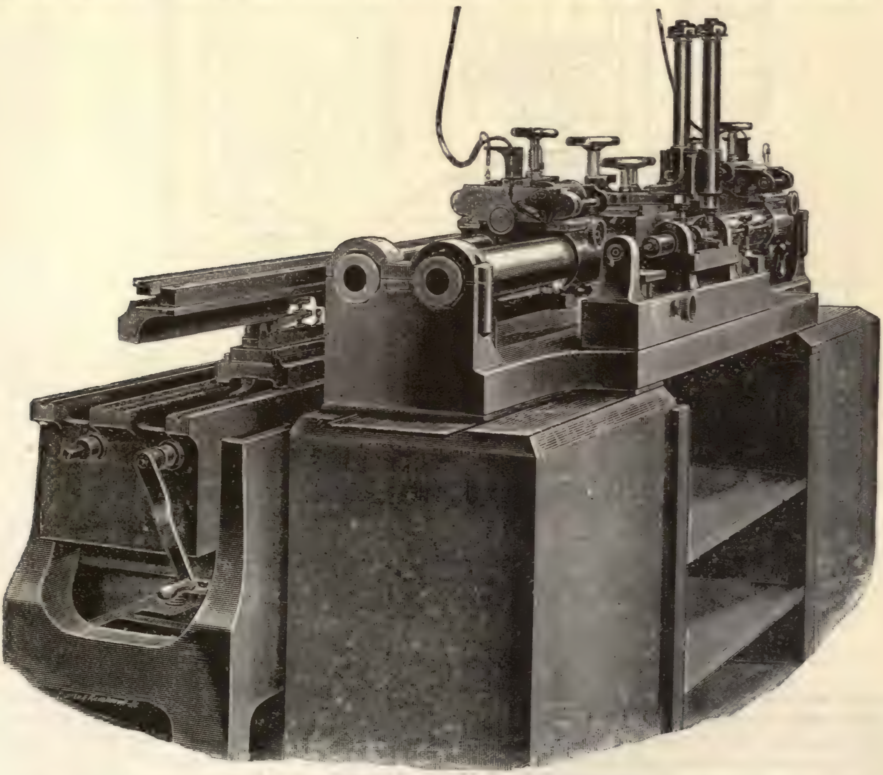

Fig. 7.—The Rogers-Bond comparator.

shown in the figure. These stops are arranged to be adjusted at any desired position along the guides, and are securely held by clamping on the under side by the handles *G* and *H*. These stops are each provided with a pair of electro-magnets, *I* and *J*, the poles of which do not quite come in contact with the armature seen at either end of the microscope-plate. Contact is made at *K* and *L*, which are hardened steel surfaces, tempered and polished, and

placed as nearly as possible in the center of mass of the plate and of the stops. The magnets are intended to overcome the unequal pressure due to ordinary contact, a rack and pinion being used to move the plate. The magnets are used to lock the microscope-plate at each end of the traverse between the stops. The use made of this sliding microscope-plate and the

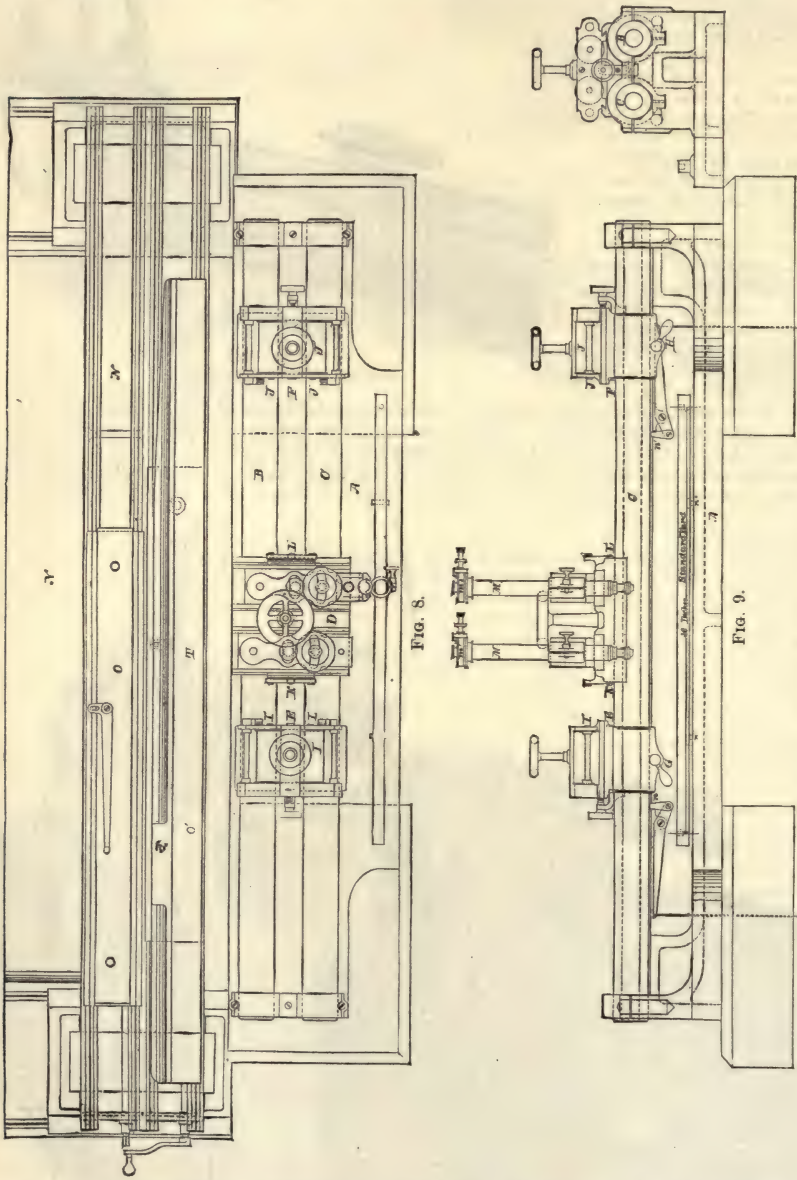

Fig. 8.

Fig. 9.

Figs. 8, 9.—Rogers-Bond comparator—details.

stops we shall see presently. Beyond the main base just described, and supported also on brick piers, is an auxiliary heavy cast-iron frame *N*, which is provided with lateral and vertical motion within the limits of zero, and of 8 and 10 in. respectively, for rough or approximate adjustment, and upon the top of this frame are two carriages, *O* and O^1, which slide from end to end, a distance of about 40 in. Upon these sliding carriages are placed tables *T* and T^1, provided with means for minute adjustment, for motion lengthwise, sidewise, and for leveling, thus permitting the adjustment of a standard yard-bar quickly, and without the necessity of its being touched with the hands after being placed upon the table until the work of comparison is completed.

"The first operation in the use of this form of comparator is to level the main base *A* (Fig. 9), then sliding the microscope-plate *D* from end to end of the steel tubular guides,

having the microscope adjusted so as to be in focus upon the surface of mercury contained in a shallow trough, over which the microscope passes, the curvature due to flexure of the guides is determined. and may be compensated for by counter-weights at the neutral points of support, n and n^1. In order to test this right-line path of the microscope-plate horizontally, the method of the 'stops' is employed, or, another method, which is that of tracing a fine line the entire length of a standard bar upon its upper surface, and, reversing the bar, tracing another line very near the first, and at an equal distance apart at each end ; then, if this distance is uniform between the two lines the entire length, it is safe to assume that the path of the plate is a straight line horizontally, and at the middle the amount of curvature, if any, and if uniform, is readily determined. This method is used by Prof. Rogers with complete success. The 'stop method' is to compare a line-measure or an end-measure bar, on each side of the center line of motion of the microscope-plate, using one microscope, and comparing this fixed length with the constant quantity before referred to, which is the distance between the stops. Should the path be a curved one, the distance between the defining lines upon the bar will appear greater on one side than on the other, in proportion to the amount of curvature existing. The length of the standard, being the length of chords of circles of different radii, seems, by comparison with the stops, to be different in length at each position, caused by the different distances from the center of curvature—about 18 in. in this instance—over which the microscope passes when placed in these two positions. By means of the proportion of similar triangles thus formed, the length of the radii may be very accurately determined. By placing different standards on one side of the line of the stops, they may be, by being compared with a constant quantity, compared also with each other.

"Another method for comparing two or more standards is to place two microscopes, one on each of two microscope-plates, upon the guides, at a distance determined by the length of one of the standards, and by replacing this one by a second, the coincidence of the lines in the eye-piece micrometer, or their variation, showing at once their relation. The microscopes may be placed horizontally in this same fixed relation, using the method invented by J. Homer Lane, and which has been successfully used in the office of the United States Coast Survey at Washington.

"The subdivision of these standards of length, which is effected by the use of this same process—the microscope-plate sliding between fixed stops. This is accomplished in the following way: A yard, for instance, is to be subdivided into three equal parts, or into three separate feet. We divide the whole length by trial into three parts, then, by setting the stops so that the microscope-plate may move very nearly the distance represented by the first one of the three parts, by readings of the eye-piece micrometer carefully taken at each end of the path of motion of the microscope, and using the finely ruled lines by which these three parts are defined, we obtain the length of this subdivision as compared with our constant quantity; then, by sliding or moving the bar along under the microscope until the second part is in place, the same operation is again performed, and so for the third, thus determining the relation of each with respect to this temporary or arbitrary standard; then, by adding the differences between these separate parts and the constant length, and taking the mean or average of these differences, from which we subtract each difference, gives us the correction to be applied to each part in order that it shall be exactly one third the total length, or, as in case of a yard-bar, giving us exactly 12 in., or the standard foot. The foot may then be subdivided in the same manner into 12 equal parts, establishing the standard inch, and, further, to $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{100}$, or even to $\frac{1}{1000}$ of an in." (See *Trans. Am. Inst. Mech. Engrs.*, vol. iv., 1882.)

Measuring-Machine: see Leather-Working Machines and Measuring Instruments, Mechanical.

Micrometer: see Measuring Instruments, Mechanical.

Middlerg's Pumper: see Milling Machines, Grain.

Mill, Grain: see Milling-Machines, Grain.

MILLING-MACHINERY, GRAIN. A very advanced step has been taken in the last twelve years by the introduction of rolls for grinding grain. This has led to a radical change of systems of milling. The old process of low-grinding in which the wheat was reduced to flour by buhr-stones at one operation, and the more advanced "new-process" system, have both given way to the Hungarian or high-grinding system, in which the production and treatment of middlings are the essential features, as also the production of as little flour at the early operations in the wheat as possible. The present systems of milling have for their object the separation of the bran from the flour-producing portions of the wheat-berry by *gradual reduction*, using chilled iron and porcelain rolls in place of buhr-stones.

The rolls have proved a powerful factor in the radical change of systems, though the purifier must receive proper recognition of its importance as a milling appliance, while the various improved sifting and cleaning devices growing out of the employment of the high-grinding system all contribute to make the latter pre-eminent as a method of producing a quality of flour fitted to meet the exacting demands of the day, and to do this profitably commercially.

It is well to note that the so-called "new-process" system, used in America prior to the introduction of rolls, may be considered a process intermediate between low-milling and the Hungarian system of high-milling. It no doubt had great influence in preparing the way for the introduction of rolls, and hastened the development of the purifier, especially in America.

It is stated that rolls were used as early as 1820, but it was twenty years later before they attracted much attention. The noted Pesth mill was the first to use rolls alone for the

reduction of wheat. For over forty years, previous to the general change from stones to rolls, this famous mill had been in prosperous condition ; and, while it stood as a prominent illustration of what rolls could do, millers generally were not inclined to the idea that the system there used could be advantageously employed on any other than the hard wheats used in that locality. Experiment and enterprise have, however, brought about the almost universal use of rolls for the various reductions, and the corresponding abandonment of the time-honored millstone. The introduction of rolls gave rise to the more scientific phase of milling. With a more general knowledge of the physical structure of the wheat-berry came a better understanding of what was necessary to be done to properly separate the bran and germ from the flour-producing portions. The system of low-grinding made the elimination of these portions impossible, since the fine, branny particles became inseparably mixed with the flour, as did also the crease-dirt held in the wheat-berry. The Austro-Hungarian or high-grinding system provides for their separation at early stages of reduction, thus making it possible to produce a clear, sharp flour. Gradual reduction, where buhr-stones are used, is attended with the same trouble as low-grinding, though in a far less degree. The fine branny particles and some crease-dirt become mixed with the flour, due to the more or less tearing action of the surface of the stone on the bran, especially with hard wheats, and subsequent treatment by reel and purifier fails to remove them. With proper treatment of the wheat by rolls the fine, branny particles and crease-dirt, so objectionable when obtained in the early stages of reduction, are almost if not wholly avoided, the middlings obtained are clean and sharp, the bran large and flaky, and the flour preserving the natural sweetness of the grain. A great impetus was given to roller-milling by the introduction, in 1874, of the Wegmann roller-mill, in which rolls of porcelain were used. These mills were introduced into England in the fall of 1876, and into the United States the spring of the following year, by Mr. Oscar Oexle, of Augsburg, Bavaria.

The essential features of this roller-mill that found ready acceptance with millers were: the squeezing action of the rolls, the character of the roll-surface, the differential speed of the rolls, and the use of springs to keep the rolls up to their work. Soft iron, stone, chilled iron, and steel rolls had previously been used, and, it was claimed, did not possess a uniform porous surface.

Close upon the introduction of the porcelain roll came the more extended use of corrugated chilled-iron rolls, especially for the earlier operations upon the wheat-berry, technically known as break-rolls. Smooth rolls had for some time been used for flattening the germ, and, indeed, for crushing wheat, while the middlings were usually treated on stones. In the early part of 1878 great interest was aroused in roller-milling, especially in America. The work done by rolls began to be appreciated. Since 1878 there has been a gradual conversion from stones to rolls. This period has been marked not alone by the introduction of rolls, but by the practical application of principles and appliances suggested by the processes employed in the treatment of the products coming from the rolls. The period is also marked by the refined mechanical construction of the various appliances now used.

Rolls.—Rolls are now made almost exclusively of chilled iron, with either smooth or corrugated surface, according to the nature of the work they have to do. The peculiar gritty surface of porcelain rolls renders them well suited for the reduction of purified middlings, but their lack of durability as compared with the chilled iron has led to a preference for the latter. Smooth rolls are generally delivered to the buyer with polished surface, but attain a dulled surface after being in use a short time. They then give the best results. This is due to the increased friction between the particles of material operated upon and the surface of the rolls. It should be understood that, as this friction is increased, the pressure required for reduction is decreased. Prof. Kick gives the coefficients of friction for polished chilled rolls on hard semolina dressed over No. 7 silk as 0·213; that for fine dull surface, 0·287; and for rolls that have been in use, 0·325. On No. 2 middlings the coefficients are given as 0·194, 0·268, and 0.306 respectively. Porcelain rolls give a coefficient of 0·404 for fine semolina, and 0·364 for No. 2 middlings. Prof. Kick also states that the whiteness of flour obtained with porcelain rolls is due to the greater fineness of the product and not the small proportion of bran impurity.

The two rolls of a pair may have the same peripheral speed, or what is termed a "differential" speed. When run equally speeded, smooth rolls act to granulate, by crushing or squeezing. When hard wheat is passed between smooth rolls equally speeded, and adjusted with proper distance between, the berry is split lengthwise, opening out the crease and setting free crease-dirt, and more or less loosening and releasing the germ. With soft wheat there is more of a crushing effect. Smooth rolls are mostly used for all reductions of purified middlings, reducing the large middlings, and when run equally speeded, flatten the germ without the rubbing action, which tends to tear it. When speeded differentially, they effect a combined crushing and rubbing action, and require less pressure to do their work than when equally speeded. This has led to the general use of differential speeds, and thereby power is saved. A differential speed of 1½ to 1 is commonly used on smooth rolls. Prof. Kick states that, theoretically considered, smooth rolls in crushing use about double the force that is required for the shearing action of grooved rolls in the actual work of reduction, or the work of crushing is twice as great as that for shearing. A further advantage of differential speed is the avoidance of "caking" of the materials on the rolls.

Corrugated rolls are generally used for all reductions other than the sizing and reduction of middlings and treatment of the germ, the number of grooves corresponding to the size of the particles of material operated upon. Many forms of groove have been employed, though

but two have attained extended use. They are the sharp and dull corrugations as represented in Figs. 1 and 2. The first sharp form of corrugation used had the sides of the flute equally inclined, but the form shown in Fig. 1, as introduced by Ganz & Co., of Buda-Pesth, Hungary, is the type of groove now employed for what are termed cutting-rolls, as opposed to the round rib or non-cutting rolls (Fig. 2). The action of the sharp groove is essentially that of shearing; relative speed of the grooves, however, being necessary in producing this effect. Rolls equally speeded would act to crush and bruise the grain, while to produce a shearing action a differential speed of 2 to 1 is necessary, that one groove may overtake the engaging grooves on the mate-roll. Consequently, these rolls are generally speeded 2 or 3 to 1. The relative position of the acting surfaces of the grooves is shown in Fig. 1, where a is the fast roll, the edge of flute pointing downward, while those of b, the slow roll, point upward. If b were made the fast roll, the action would be that of crushing and rubbing.

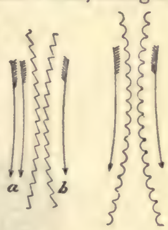

FIG. 1. FIG. 2.
FIGS. 1, 2.—Corrugated rolls.

With the sharp flute four dispositions of the acting edges are permissible, as shown in Fig. 3, thus providing for different qualities and condition of the grain—as, sharp to sharp for tough wheat, and dull to dull for hard wheat; with the other arrangements for intermediate qualities.

In December, 1881, Mr. William D. Gray, of Milwaukee, Wis., took out letters-patent for a form of corrugation in which the ribs were abrupt on one side and rounded on the other, thus obtaining the cutting and non-cutting effect according to the dispositions of the acting sides of the flutes. With sharp-cut rolls the edges left by the corrugating tool are soon lost, a day or two, it is stated, being sufficient to make them feel smooth. They can be used from one and a half to two years before requiring to be recut. A twist or spiral direction along the roll is given the grooves to prevent those of one roll catching in the grooves of its mate. This also tends toward a more severe shearing action.

The direction of the twist may be the same on each roll of a pair, or disposed in opposite directions. In the former case the grooves cross at line of contact of rolls, while in the latter they are parallel at that line. On May 25, 1880, Mr. John Stevens, of Neenah, Wis., received letters-patent for a roll having a dress formed of grooves with rounded divided ridges, as shown in Fig. 2.

For this form of corrugation is claimed less cutting of the bran and breaking of the germ. The number of grooves employed for the several stages of reduction increase as the products become finer. For the five successive break rolls usually employed they may be 10, 12, 14, 16, and 20 grooves per in. of circumference of roll. The bran-rolls may have 24, and the middlings reduction-rolls 32 grooves per in. With sharp corrugations there are more grooves than with the round, and practice varies in regard to the numbers given above, some preferring finer-grooved rolls. The differential usually employed for breaks is $2\frac{1}{2}$ to 1, while the same, or 3 to 1, is used with scratch-rolls—rolls with dress formed of shallow-waved grooves, 32 per in. The diameters of rolls generally used are 9 and 6 in.; the lengths, 12 to 30 in. Nine-in. rolls are usually run at 300 to 400 revolutions per min., and the 6-in. rolls 600 revolutions, the peripheral speed being 706 to 942 ft. per min. First-break rolls run at these speeds will pass from 90 to 112 lbs. of wheat per in. of length of roll per hour. Where six breaks are employed, an increase of about $1\frac{3}{8}$ to $1\frac{1}{2}$ times the grinding length of first-break roll is made, this taking place at the third or fourth and following breaks.

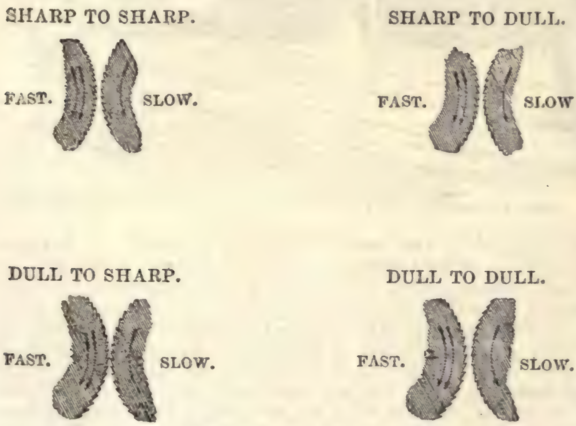

FIG. 3.—Corrugated rolls.

Variation in practice makes it difficult to state proportions of grinding surface for middling-rolls. A given size of roll grinding middlings will handle about three fourths the weight of material that the first-break roll of same size will pass. The pressure on roll-bearings is the controlling factor in the calculation for power required, the actual work of granulation being comparatively insignificant. Pressures up to 3,500 lbs. per bearing are used, the work of friction thus being for a 2-pair mill 15 horse-power. About 1,000 or 1,500 lbs. per bearing are perhaps average pressures for 9-in. rolls, having spindles $2\frac{7}{8}$ in. diameter. Six-in. rolls are used with 600 to 1,000 lbs. per bearing.

Roller-Mills.—In Fig. 4 is shown the well-known Stevens roller-mill. The frame is of the "skeleton" construction, composed of the two side-frames or legs, which are bolted to a rectangular bed or top. The rolls are mounted in boxes as shown, the two inside boxes being rigidly fastened to the bed, the two outer ones sliding on finished surfaces. A V-shaped gib,

bolted to the bed, preserves the linear motion of the sliding-box. Relative position of the rolls is attained by the adjustments, as shown in Fig. 5. At each corner of the bed of the machine are cast lugs which sustain the backward thrust of the movable rolls. Into these

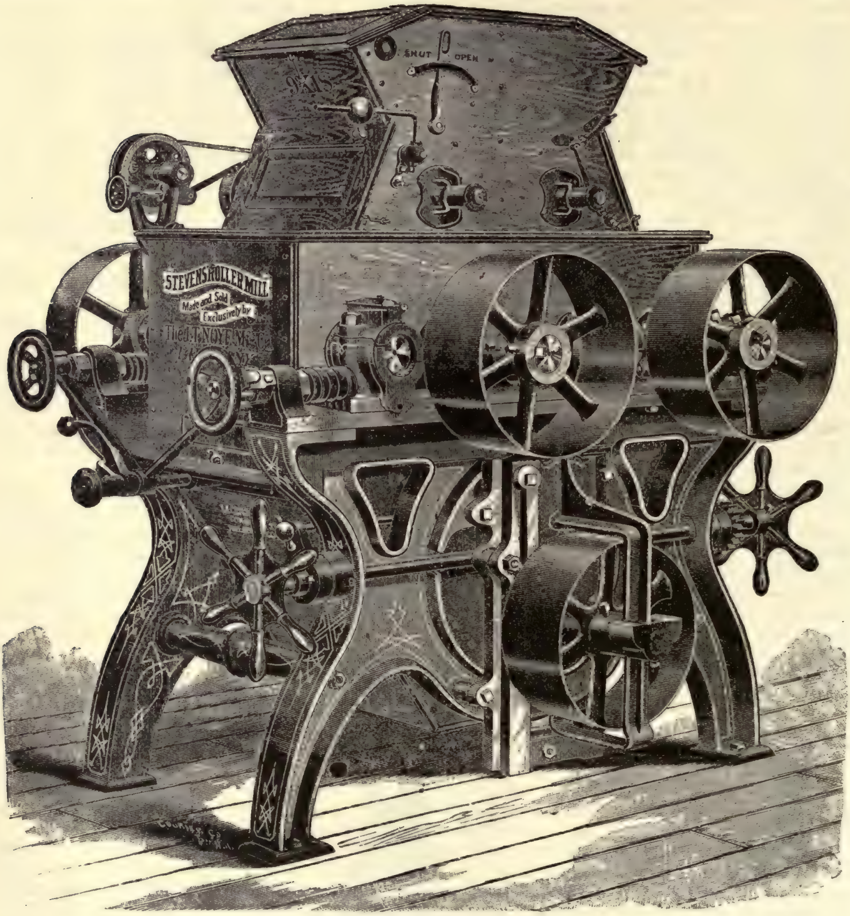

Fig. 4.—Stevens roller-mill.

lugs are fitted threaded sleeves, through which the hand-wheel stem is passed. A hexagon head on the outer end of this sleeve provides for turning it, and it is screwed firmly into the lug, so as to act as a stud for the spring-nut shown to work upon. The hand-wheel stem is threaded at its inner end, and passing through a hexagon nut seated in the sliding-box, abuts against the fixed box as shown. Turning the hand-wheel moves the sliding-box away from or toward the fixed box, and the proper grinding tension or pressure is secured by setting up the spring-nut. Vertical adjustment of the fixed roll is secured by the parts as shown in Fig. 6. The adjusting screw and dowel in which the box rests raise or lower it, while the binding screws secure the box firmly to the brackets after the necessary adjustment has been made. The dowel aids to preserve the fixed lateral position of the roll-bearing. The boxes project beyond the end of the short roll-necks and have enlarged recesses to retain the oil and prevent its running down into the frame. The tightened pulley, mounted in its spindle, runs in a frame vertically adjustable by means of a rack and pinion operated by the cross-shaft shown, which latter is held from rotating by pawl and ratchet-wheel, and is readily turned when desired from either end of the machine. The pulleys shown drive the first rolls of each pair, their mates being driven either by belts or gears, arranged to provide the differential of roll-speed, the latter varying generally between 3 to 1 and 1 to 1. The spreading device shown at the front of the machine provides for the simultaneous movement of the ends of the movable roll without disturbing the working adjustment as made by the hand-wheels at each end of the roll. Projecting from the bed is a threaded stud, on which turns the curved arm shown, the hub of this arm being threaded to fit the thread on the stud. In front of this arm is a dog with hub threaded the same as the arm, and having its outer end bent so as to form a stop for the curved arm to rest against. At the outer end of the stud is a small hand-wheel hav-

ing a left-hand thread. Extending from the stud to each hand-wheel are levers, one end of each pressing against the hub of the curved arm, the other ends bearing against the inner end of the hand-wheel hubs. Near the hand-wheel stem and attached to the threaded sleeve through which it passes, is placed a fulcrum, the latter being thus between extremities of the levers—the operation of the whole being such that by rotating the curved arm, say from left to right, it advances along the stud, pushing the inner lever-ends toward the frame, and forcing the hand-wheels in the opposite direction, and therefore the roll away from its mate.

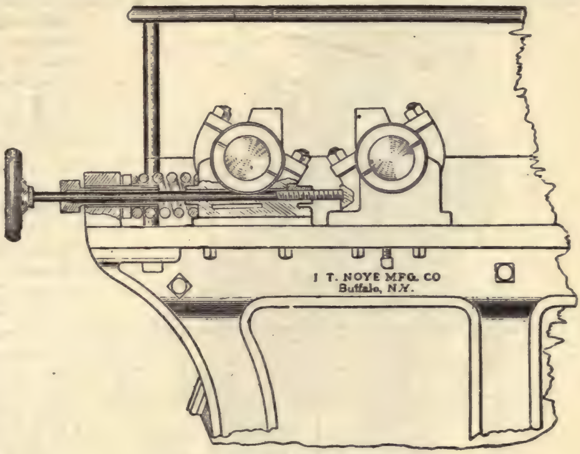

Fig. 5.—Roller adjustment.

By advancing the dog along the stud and setting up the small hand-wheel tight against it, any desired position of the curved arm can be maintained. Rotating the curved arm, the dog remaining fixed, alters the adjustment of the rolls, but they can be restored to their previous adjustment by bringing the curved arm back to the dog. Generally about ½-in. is the maximum spread of rolls required. The wooden housing is parted horizontally at the roll centers, the top being lifted bodily so that the rolls can be easily removed when necessary. In the top is placed the feed-device. This consists essentially of two gates, extending across the top part of the housing, and swung on axes at their upper edge, and connected by levers and links, so that motion of one implies that of the other. The upper gate forms one side of a V-shaped hopper, into which the material falls. The lower edge of the other gate approaches a feed-roll located as shown by the extended bearings near the bottom of feed-hoppering. Fastened to the shaft on which this gate swings is the arm carrying the counter-weight.

When no material is in the hopper, this lower gate is swung against the feed-roll, but as material enters in the upper gate it accumulates in the hopper formed by this gate and the stationary cant-board at center of the housing, until the weight is sufficient to overcome the effect of the counter-weight, when this upper gate swings down, allowing the material to pass to the space below it, where it meets the lower swinging gate, and passes between its lower edge and the feed-roll to the grinding-rolls beneath. The secondary hopper is provided so that material coming into it from the first hopper will have a chance to distribute itself over the entire length of the feed-roll. The greater the quantity of material pressing against the upper gate, the greater the opening at the feed-roll, and consequently the greater the quantity passing to the grinding-rolls. The desired quantity of feed can be obtained by adjusting the counter-weight on its arm. The lower part of the housing contains the brushes for cleaning the rolls, and the door in front permits access to materials passing from the rolls. The feed-rolls are driven by a single belt passing from the neck of one slow roll over each pulley on the feed-rolls, and the tightener-pulley shown at top of the housing.

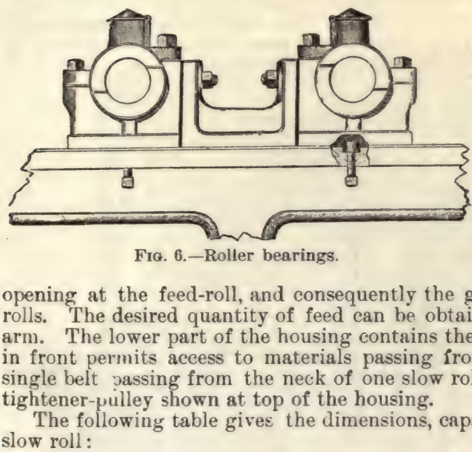
Fig. 6.—Roller bearings.

The following table gives the dimensions, capacity, etc., of mills using a belt-drive on the slow roll:

	9×30.	9×24.	9×18.	9×15.	6×20.	6×15.	6×12.
Length — Space over all	5′-2″	5′-2″	5′-2″	5′-2″	4′-6½″	4′-6½″	4′-6½″
Width — Space over all	5′-7⅞″	5′-0⅞″	4′-5⅞″	4′-0⅞″	4′-3¾″	3′-7¾″	3′-4¾″
Height — Space over all	5′-6″	5′-6″	5′-6″	5′-6″	5′-0″	5′-0″	5′-0″
Length — Space on floor	4′-5″	4′-5″	4′-5″	4′-5″	3′-8″	3′-8″	3′-8″
Width — Space on floor	3′-5½″	2′-11½″	2′-2½″	2′-0½″	2′-7″	2′-2½″	1′-10″
Pulleys, fast rolls	18″×7″	18″×6½″	16″×6″	15″×6″	10″×5½″	10″×5″	10″×5″
" slow rolls	18″×6″	18″×5½″	16″×5″	15″×5″	10″×4½″	10″×4″	10″×4″
Floor to center of pulleys	3′-2″	3′-2″	3′-2″	3′-2″	2′-11½″	2′-11½″	2′-11½″
Speed	400	400	400	400	600	600	600
Capacity, bbls. per 24 hours	500 to 600	400 to 500	250 to 300	200 to 250	200 to 300	150 to 200	120 to 150
Power required (h.-p.), approximate	4 to 6	3 to 5	2 to 4	2 to 3	1½ to 2½	1 to 2	1 to 1½

Several makes of roller-mills are made with box-frame construction, and with rolls mounted in swinging arms. The Gray mill is the pioneer in this form of construction. In this mill the vertical adjustment of the rolls is obtained by an eccentric bush fitting over the stud, on which the swinging arms are suspended. Motion to the rolls is obtained by the use of one belt, a counter-shaft and pulleys running in boxes hung to the frame acting to transmit motion from the main belt to the slow rolls, a pulley on one end of the counter being the tightener pulley for the main belt, while the pulley on the other end of the counter serves to carry the slow-roll belt

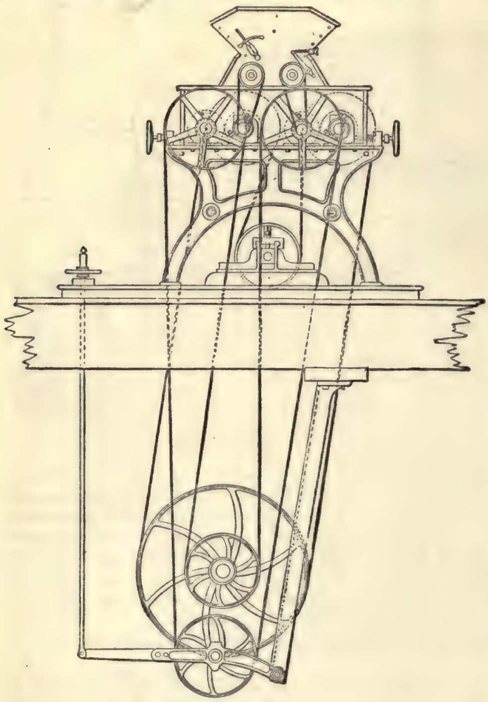

FIG. 7.—Driving-gear.

Fig. 7 shows a method for driving both fast and slow rolls in a Stevens double mill which has proved satisfactory. The large pulley on the line-shaft beneath the floor drives the fast rolls, the small pulley the slow ones. The means for tightening the belts are readily seen. In some short systems of milling only two or three breaks are made, and in such cases the machines shown in Fig. 8 can be used especially where economy of room is necessary. The machine shown has two pairs of corrugated rolls and two reciprocating sieves. The grain passes through the first or upper pair of rolls and on to the first or upper sieve. A separation of the product is here made, flour and middlings passing through the sieve and away from the machine; the large unreduced portion passes over the tail of the sieve on to the second pair of rolls, and from there on to the second sieve, when a second separation is made. The sieves have traveling brushes beneath them, thereby enabling the meshes to be kept clean. The machine is driven by a single belt, and adapted to mills of 75 to 150 bbls. capacity, the power required being from $3\frac{1}{2}$ horse-power with 9×14 in. rolls to 6 horse-power with 9×30 in. rolls.

In Fig. 9 is shown a type of roller-mill used in grinding corn, as made by the Nordyke & Marmon Co., of Indianapolis, Ind. Three pairs of rolls are used, disposed so as to break the grain successively. The first pair are adjusted solely by the hand-wheels shown, while the middle and lower pairs are spread or thrown together by a single lever. The fast roll of each pair is driven by one belt from the main shaft. The slow rolls are driven by gears. The machine is built very rigid in order to meet the hard usage found in this class of work. In a mill using rolls 9×24 in. the capacity is stated to be 65 to 100 bush. per hour, and the power required 12 to 20 horse-power. The upper pulley runs 400, the middle 445, and the lower 500 revolutions per min. The pulleys are 20, 18, and 16 in. diameter and $8\frac{1}{2}$ in. face for upper, middle, and lower drives respectively.

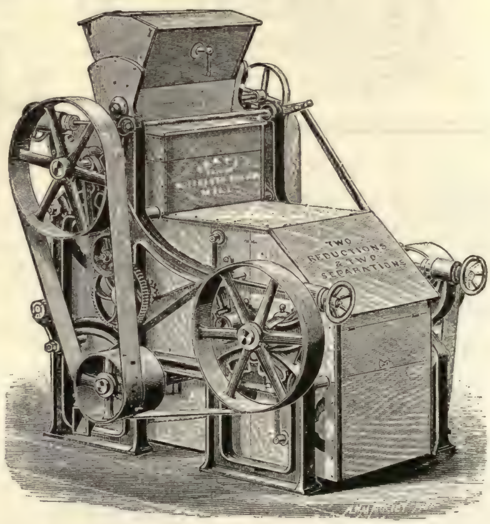

FIG. 8.—Gray roller-mill.

Scalping-Reels.—The scalping-reels handle the break-roll products, successively separating the break flour and middlings from the coarser material after each break. The reel-frame is made either hexagon or round in form. In the former the tail end is larger than the head; in the latter the shaft is depressed at the tail end to carry the material through. The reel-shaft is of iron, and the wooden ribs are attached to iron spiders on the shaft. The wooden

head is provided with the usual opening, through which is introduced a feed-spout with the customary conveyor-spiral to feed the material into the reel. The round reels, in scalping as in flour-dressing, are receiving much attention as to detail, and are gaining in popular favor. Scalping-reels are clothed with wire cloth, silk cloth, or perforated steel, and are from 18 to 36 in. diameter and from 4 to 9 ft. long. They are now commonly driven by belt or chain direct from the line or counter shaft, and are run about 28 revolutions per min. for a 32-in. reel. The slant is from ¼ to ⅝ in. per foot. The reel-chests are usually made to conform to the style and sizes of those of the centrifugal and round reels for flour-dressing described later. The speed should be about 50 revolutions per min. for 18-in. reels to 28 revolutions for a 32-in. reel.

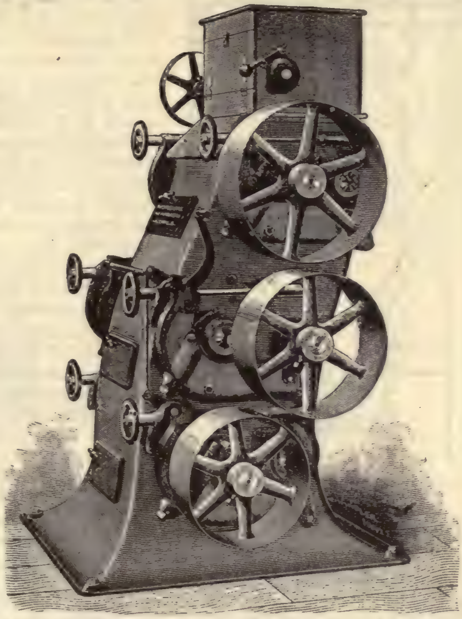
Fig. 9.—Roller-mill for corn.

Centrifugal Reels.—In recently erected flour-mills the old hexagon bolting-reel has been supplanted by the centrifugal and round reels, and especially has the latter been favorably received. The hexagon reel and its chest, the former 32 in. in diameter and from 12 to 16 ft. long, the latter exceeding these dimensions, have been found too cumbersome for modern purposes, especially in America, and reels considerably smaller and of far greater capacity are now found taking their places. Fig. 10 is a perspective view, and Fig. 11 a cross-section of a centrifugal reel, as made by the E. P. Allis Co., of Milwaukee, Wis. Referring to the cross-section, it will be seen that on the beater-shaft are placed the spiders to which are attached the beaters, the latter running lengthwise of the reel and inclined to a radius from the center of shaft, acting thus to throw the material against the bolting cloth, which, mounted on a reel-frame, surrounds the beaters, etc. The latter are set close to the cloth to keep the stock thoroughly in motion, preventing accumulation and thereby giving full action to the reel. They run spirally lengthwise of the reel, thus carrying the material gradually toward the tail end,

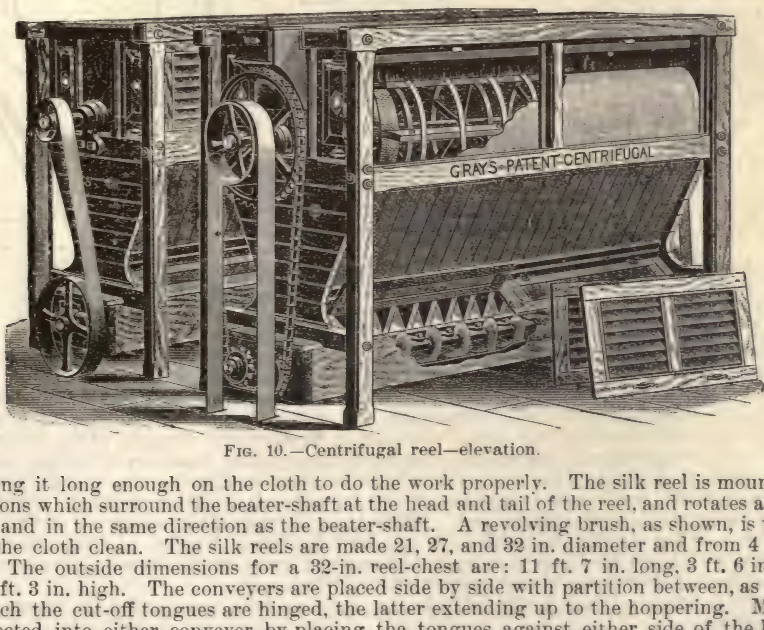

Fig. 10.—Centrifugal reel—elevation.

retaining it long enough on the cloth to do the work properly. The silk reel is mounted on trunnions which surround the beater-shaft at the head and tail of the reel, and rotates at a less speed and in the same direction as the beater-shaft. A revolving brush, as shown, is used to keep the cloth clean. The silk reels are made 21, 27, and 32 in. diameter and from 4 to 8 ft. long. The outside dimensions for a 32-in. reel-chest are: 11 ft. 7 in. long, 3 ft. 6 in. wide, and 5 ft. 3 in. high. The conveyers are placed side by side with partition between, as shown, to which the cut-off tongues are hinged, the latter extending up to the hoppering. Material is directed into either conveyer by placing the tongues against either side of the hopper. With the centrifugal it is necessary to provide some safeguard to prevent foreign substances from entering the reel. This should be a basket of wire-cloth or other suitable material which

can be readily cleaned. In this class of machines the speed of silk reel should not be so great that the material is held against the cloth by the centrifugal force due the speed. The speed of beater-shaft is usually 10 or 12 times that of the silk reel, a usual speed for the latter being 18 to 20 revolutions per min. It is the aim of makers of centrifugals at the present time to direct the material against the silk at a very acute angle, so that sliding of the material over the surface of the cloth shall take place, fully recognizing the value of this action as obtained with the now old style hexagon reel.

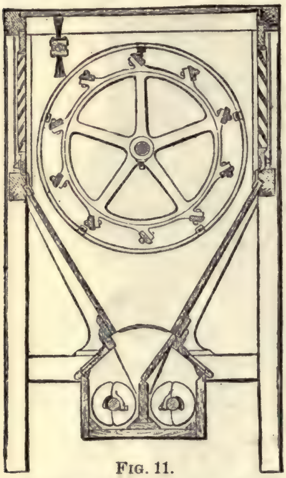

Fig. 11.
Centrifugal reel—cross section

Round Reels.—A later machine, and one, it is claimed, that overcomes the alleged defects of the centrifugal, is shown in cross-section at Fig. 12. This class of machine has rapidly gained in favor since its introduction, about four years ago, and is said to have fully demonstrated the superiority of the round-reel bolting system. The cut shows a flour-dresser made by the Allis Co., the perspective view of which is almost identical with that of the centrifugal already noticed. The reel, mounted on the main shaft, consists of a substantial casting at each end, upon which wooden rings are placed, to which the cloth is attached. Round rods connect the head and tail end castings, and to these are attached rib-rings for the cloth and carriers, preventing contact of cloth with the rods. Within these rods is placed a light sheet-iron drum, fastened firmly to the shaft. The carriers are pitched spirally toward the tail, leading the stock continually in that direction. Sufficient space is left between the outer edge of the carriers and the cloth, also between the inner edge of the carriers and the drum, to enable the stock to bolt properly without heating or rough handling, thus avoiding flouring of the stock. The flouring of the material, as alleged to take place with the centrifugal reel, as also the increased quantity of bolting-cloth necessary, are factors against the centrifugal; while the great capacity and effectiveness of the round reel has led to its extended adoption. The room occupied and power required are greatly decreased as compared with the hexagon reel—the round reel, it is claimed, doing the same work as the hexagon, with from one half to one third the length of reel. Inventors have striven to produce a reel in which the full circumference could be utilized for sifting, in place of only the lower portion, as is the case with the hexagon reel. The centrifugal and round reels are intended to do this, the latter appearing to have accomplished the object in a more satisfactory manner. The difference in the action of these two machines is readily understood by an inspection of Figs. 11 and 12. In erecting new mills a great saving in millwright work is effected by the use of this class of reel. They come from the manufacturer complete and ready to be set in position, one being readily placed on top of another. In mills using the complete system of centrifugal or round reels the saving in room is stated to be about one half, and the saving in first cost of machines nearly one third. The reels are driven by belts, and are usually made from 21 to 32 in. diameter, and the cloth is from 6 to 8 ft. long. the approximate power. as given by the makers, being 0·2 horse-power and 0·6 horse-power respectively.

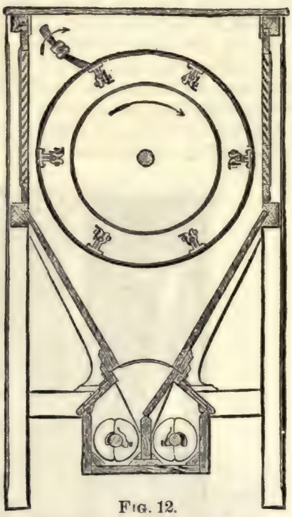

Fig. 12.
Round reel—cross section.

Purifiers.—The George T. Smith purifier, so well and favorably known, is regarded as the standard machine of its class. The main features of this machine have never been departed from, and are: An upward current of air through the covering of a reciprocating sieve, clothed with silk of increasingly coarser mesh from head to tail; an inclosed air-space above the sieve, divided by transverse partitions into separate compartments having practically no communication with each other, and each opening into the chamber of an exhaust-fan through an adjustable valve, arranged to regulate the strength of the air-current through each compartment separately; a series of dust-settling chambers or testing pockets, corresponding in number to the compartments above mentioned, and a brushing device operated automatically and working against the under side of the sieve clothing. This combination has proved a very efficient one. There are numerous other makes of purifiers, but the Smith purifier may be regarded as a standard machine. The use of dust-collectors in connection with these machines has led to economy of space and increase in convenience in providing for the dust-laden air coming from the purifier-sieve.

The Prinz dust-collector is favorably known, and has long since settled the knotty dust-room question.

A new principle, that of the "cyclone" dust-collector, has recently been put into practical operation, the essential features of which are embodied in the machine noted below.

This machine, which bids fair to be a formidable rival to the sieve purifier and attached dust-collector, was lately devised by Mr. N. W. Holt, of Manchester, Mich., and made by the Knickerbocker Co., of Jackson, Mich. Fig. 13 shows the exterior, and Figs. 14 and 15 the interior. The stock is fed into the feed-spout *A* upon each side of the machine. Two grades

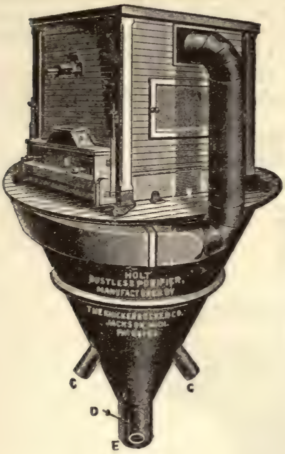

Fig. 13.

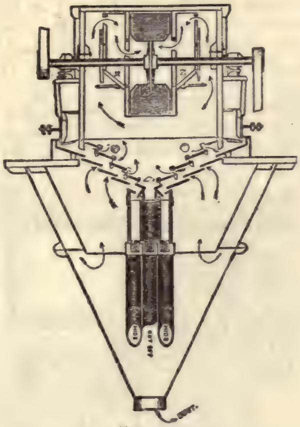

Fig. 14.

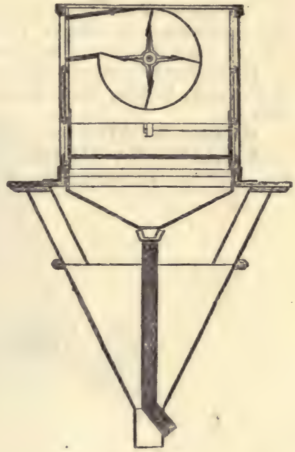

Fig. 15.

Figs. 13–15.—Holt dust-collector.

of stock may be handled at the same time. From the feed-spout it passes to the feed-box *B*, which vibrates with the sieve or shaker, causing the stock to flow over the lower overlapping shelves in a thin, even sheet, where it is acted upon by the air-current, as shown. The purified middlings then pass out at spouts *C C*, the cut-off at *D*, and the dust at spout *E*. The fan placed at the top provides the air-circulation. The upper series of shelves shown are air-gates adjustable to suit the intensity of the air-current required at the several points of the sieve, while gates at the eye of the fan control the air-circulation as a whole. The dust-laden air is discharged from the fan through the pipe leading downward from the top part of the purifier into what is called the cyclone part of the machine, where the dust and air separate, the dust eventually settling at the bottom of the cone-shaped part and passing away from the machine, the air returning through the sieve, to be again used. The same air is used over and over, and, not being renewed from without the machine, excludes the possibility of smoke or dust from the external atmosphere affecting the products. No cloth is used, and the air being confined inside the machine renders it dustless. The power required is very small, a driving-pulley 7 in. diameter and 3¼ in. face, running 600 revolutions per min., being all that is required to drive it. The capacity of the machine as now made is equivalent to one medium sieve purifier.

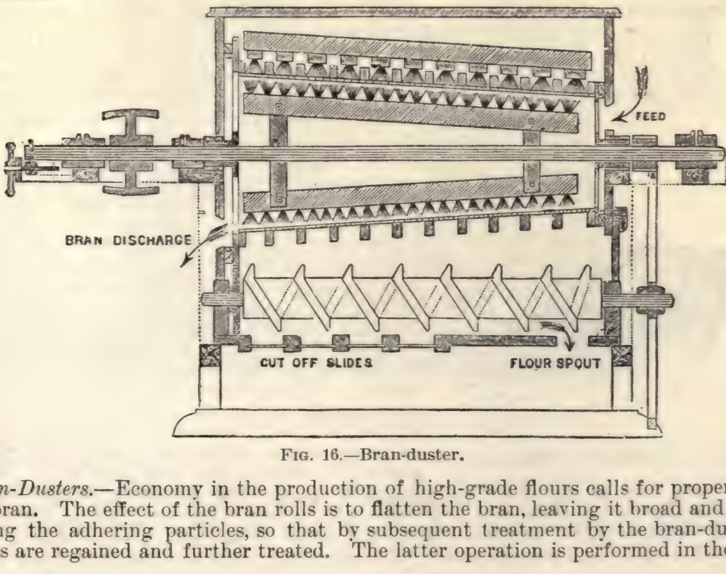

Fig. 16.—Bran-duster.

Bran-Dusters.—Economy in the production of high-grade flours calls for proper cleaning of the bran. The effect of the bran rolls is to flatten the bran, leaving it broad and flaky and loosening the adhering particles, so that by subsequent treatment by the bran-duster these particles are regained and further treated. The latter operation is performed in the machine

shown in Fig. 16, which consists of a rapidly revolving shaft on which are mounted brushes running lengthwise of the shaft and made adjustable toward or from the slowly revolving dusting-case which surrounds them. This dusting-case, clothed with fine wire-cloth, is, in this machine, cone-shaped, the material being fed and discharged as indicated in the engraving. A brush outside the wire-cloth keeps it clear, and the conveyer beneath serves to handle the products coming through the cloth. The shaft makes from 400 to 450 revolutions per min., according to size of machine, the pulleys 14 × 7 in. and 8 × 5 in. respectively. The sizes of machines given handle the offal from mills of 600 to 60 bbls. capacity in 24 hours.

Books for reference: *Gradual Reduction Milling*, by L. U. Gibson; *Flour Manufacture*, by F. Kick, Powles' translation, 1888; *Die Österreichische Hochmüllerei*, by Franz Kreuter, 1884.

Milling-Machine: see Key-Seat Cutters and Nut-Facing Machine.

MILLING-MACHINES. HORIZONTAL SPINDLE MILLING-MACHINES.—*Universal Milling and Boring Machine.*—Fig. 1 shows a combined boring and milling machine made by the

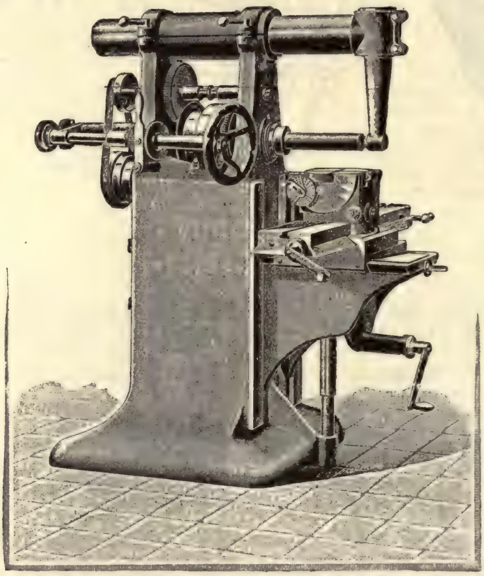

FIG. 1.—Boring and milling-machine.

States Machine Co., of Newark, N. J. The inner or boring spindle, reamed for a Morse socket, has a power-feed 13 in. in both directions, and its thrust, directly from the back, is operated by a screw attached to it by an interlocking device. Feed is taken from a worm on the main spindle and is geared to a feed-shaft for hand or power feed. This feed-shaft, on its front end, has a hand-wheel, giving a quick return. From there it extends to the end of the main spindles, where it is geared to the feed-screw by a sensitive friction-gear, so that the power-feed can be set, in case a drill be dull or feed too fast, to regulate the thrust automatically, as a workman would by hand. The overhead arm supports a detachable drill-jig pendant. The platen has an adjustment graduated to ·001 in., and has deep-grooved T-slots open at either end, with a circular T-slot and attachment-seat in the center. The platen can be turned at any angle or all the way around, and fastened where desired. The knee has an adjustment up and down, graduated to ·001 in., and the saddle upon the knee has an adjustment to and from the column graduated to ·001 in. When used as a milling-machine the main spindle, 3 in. in diameter, does all the milling independent of the telescoping spindle, which does all the boring and drilling. Milling arbors and chucks screw on to the main spindle as face-plates do on lathes. The milling-feed is driven from the overhead gears, which are mounted on the milling-feed shaft, and slide into position endwise upon feathered keys; therefore either of them may be engaged with the spindle-gears. The feed-shaft pulley is belted to feed-cones, and these are connected to the platen by a pair of universal joints. There are 16 changes of milling-feed. The platen is fed by power 24 in., and operates at angle adjustments as well as the usual cross-position. The elevating, cross, and traverse adjustments are

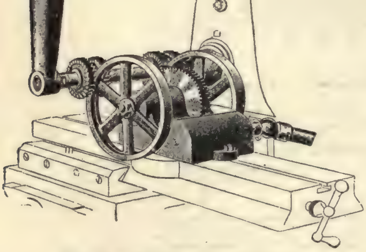

FIG. 2.—Circular attachment.

respectively 18 in., 24 in., and 12 in. A circular milling attachment for this machine, shown in Fig. 2, is used in machining gear-blanks, balance-wheels (which are milled between the spokes as well as the periphery), pistons, and such other circular pieces as need the whole or part of their surfaces concentric to a given point. It is especially useful in duplicate work, when many parts of the same character are required.

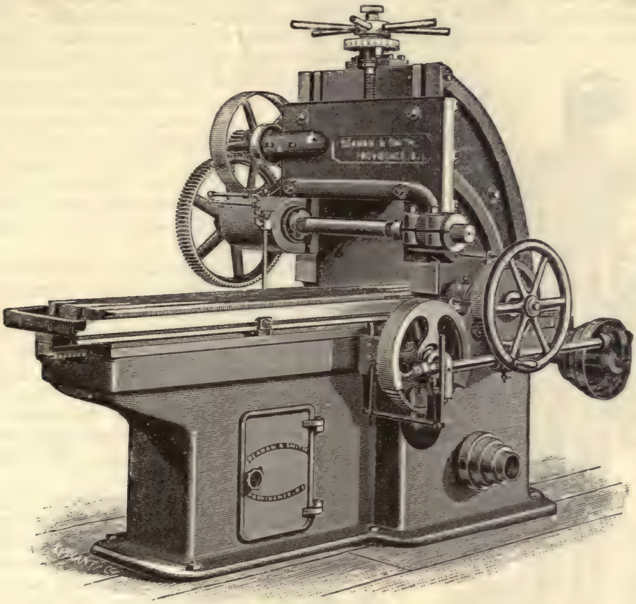

FIG. 3.—Horizontal milling-machine.

Beaman & Smith's Horizontal Spindle Milling-Machine (Fig. 3) is intended for long and heavy cuts, such as guide-bars, connecting-rods, key-seating shafting, axles to 10 in. diameter, etc. The table is 14 in. wide, has three T-slots, moves by a cut rack, and is so geared as to be easily operated by hand. The cross-head is gibbed to the housings, and is adjusted by a

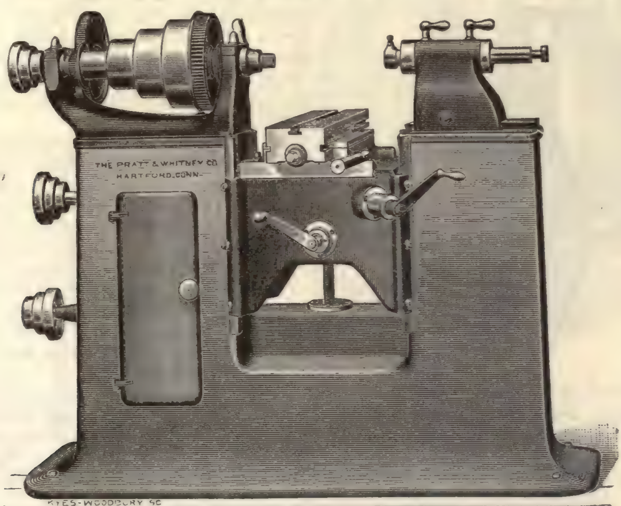

FIG. 4.—Milling-machine.

screw with graduated dial. The spindle runs in bronze bearings, is driven by a 3½-in. belt over a 16-in. pulley, through gearing in the ratio of 5 to 1, arranged for 4 speeds. Provision is made for horizontal adjustment of cutters. The feed is actuated by means of a worm and gear. It can be thrown out by hand or stopped automatically, and is the full length of the table.

Grant's Double-Column Milling-Machine.—Fig. 4 shows Grant's double-column milling-machine, as built by the Pratt & Whitney Co. More rigidity than is possible in a single-column machine is obtained in this by placing the head-stock and foot-stock on a double column, and fitting the elevating slide between the uprights with provision for clamping it firmly to each when in use. Both vertical and longitudinal adjustments of the table may be varied minutely by aid of graduations in thousandths of an inch conveniently placed.

Reed's Double-Head Milling-Machine.—Fig. 5 shows a machine built by F. E. Reed, of Worcester, Mass. It is designed for milling the ends of girts, beams, and a large variety of other long work. The illustration shows the machine milling loom-girts, the ends of which are 4 by 7½ in. It is said to finish 88 of them in 10 hours. It is provided with one sliding-head, to admit of milling any length desired on both ends at the same time. The shoes in which the tables slide can be moved together or separately by means of rack-and-pinion gear. The tables have automatic feed, or can be run by hand, together or separately.

FIG. 5.—Reed's double-head milling-machine.

VERTICAL SPINDLE MILLING-MACHINES.—Milling-machines with vertical spindles and traversing or rotating tables for holding the work have come largely into use within the past few years. They offer many advantages in the range of work of which they are capable, and in the convenience and solidity with which the work is held. They are made in quite a variety of forms by different makers, much originality being shown in their design. We illustrate below several forms.

Fig. 6 represents the *Brown & Sharpe Vertical Spindle Miller.* This is a convenient machine for the various operations of milling which can be done with an end or face mill; the work being held upon the platen, and the spindle standing vertically over the same, enables the operator to plainly see or to guide the work, to follow any irregularity of outline of any raised surfaces to be milled. The platen has longitudinal and transverse movement. The spindle has a hole throughout its length, through which a bolt is passed for holding the arbors. The adjustment of the spindle is made by raising the column, a fine adjustment being obtained by a graduated collar-nut reading to thousandths of an inch. The feed is automatic at will, in either direction, stopping automatically at any required point.

The Hilles & Jones Milling-Machine.—Fig. 7 shows a new design of vertical milling-machine built by Hilles & Jones, of Wilmington, Del. It is adapted for locomotive, engine, and other heavy work. A radial crane is attached for lifting heavy pieces. The table is furnished with both rotary and traverse motions.

The Beaman & Smith Milling-Machine.—Fig. 8 represents a vertical milling-machine built by Beaman & Smith, of Providence, R. I., for surface milling, using face or end cutters from 4 to 12 in. in diameter.

E. W. Bliss Co.'s Vertical Milling-Machine, shown in Fig 9, is designed for die-work, as well as for much work of a general character hitherto done on planing and shaping machines. Circular, longitudinal, and cross feeds are provided, the latter being automatic, and having four changes of speed. The head which carries the spindle is adjustable as to height, and is counterbalanced. The spindle is suited for operating side, bottom, and facing cutters.

Vertical or Angular Attachment for Milling-Machines.—This attachment (Fig. 10) is built for use on the milling-machine manufactured by Pedrick & Ayer. It is adapted to the cutting of racks, spur and bevel gears, profiling, or angular milling, etc. It is secured to the head of the milling-machine, and is driven by a socket fixed in the spindle, which is key-seated to fit the keyed stud in the attachment. Through the medium of a pair of mitre-wheels this stud drives a spindle at right angles to the vertical attachment. This spindle is geared with a shaft in line with it, which is utilized as a cutter or saw arbor for cutting racks, sawing up stock, etc.

Locomotive Cylinder-Port Milling-Machine.—This machine (Fig. 11), built by Beaman & Smith, of Providence, R. I., is designed especially to mill the ports of locomotive cylinders.

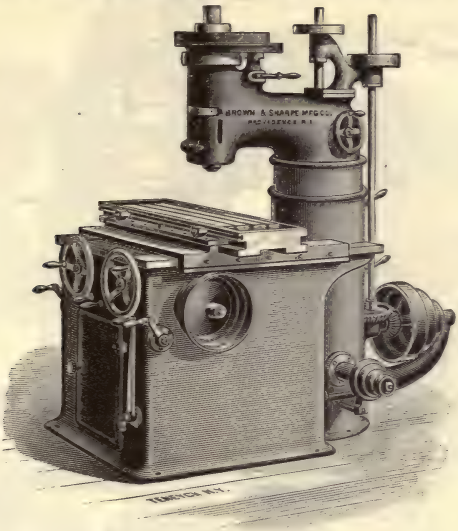

Fig. 6.—Vertical spindle miller.

It can be readily attached to any standard locomotive cylinder. The frame or bed is fastened to the steam-chest seat, and the uprights are moved on the frame by means of racks and

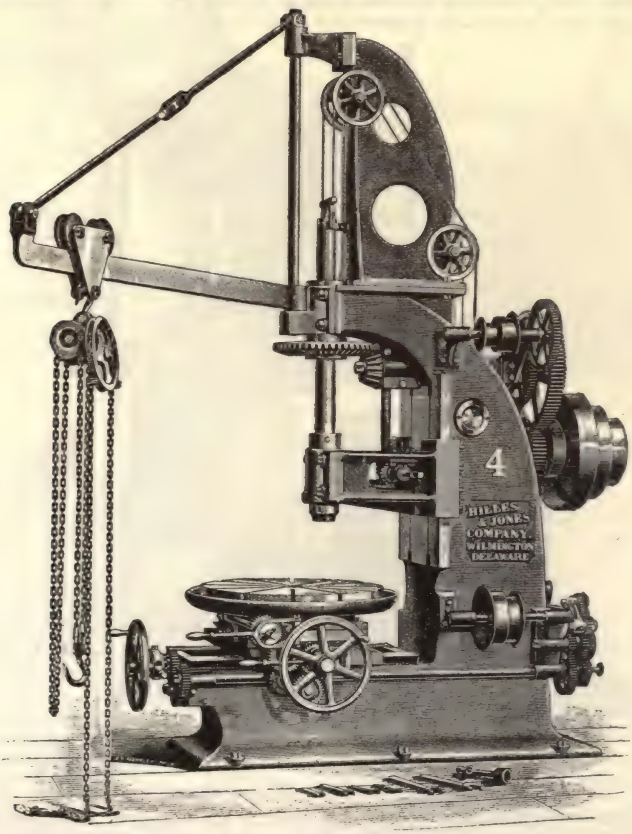

Fig. 7.—Vertical milling-machine.

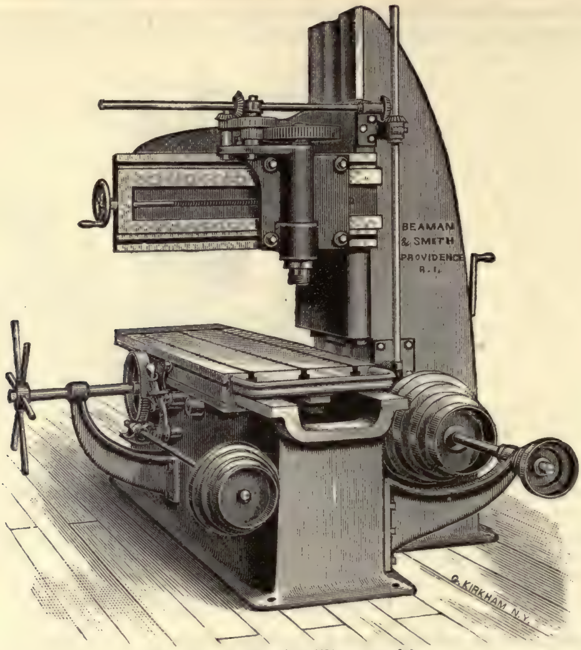

Fig. 8.—Vertical milling-machine.

pinions until the milling-cutter is over the ports as desired, and are then fastened. The cross-head carrying the spindle-saddle is lowered similar to that of a planer, until the milling-cutter

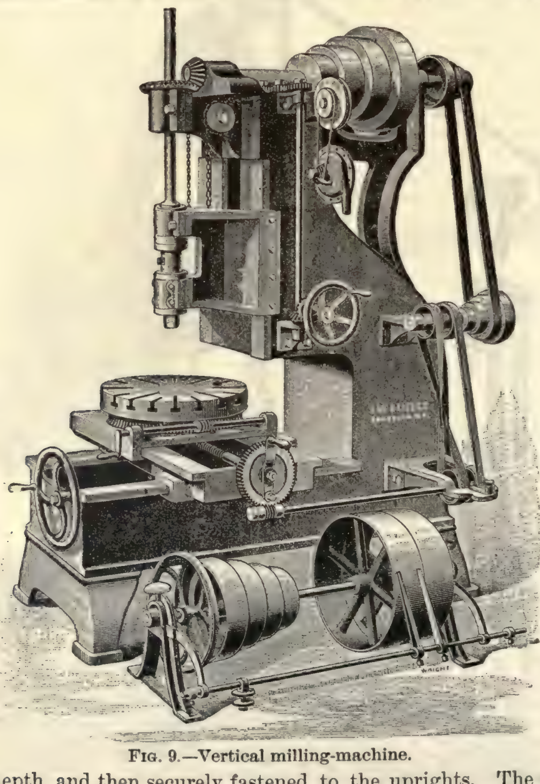

Fig. 9.—Vertical milling-machine.

is at the required depth, and then securely fastened to the uprights. The spindle is of steel, and runs in conical bronze bearings with adjustment to compensate for wear, and is driven by a cone. The feed is automatic in either direction.

Portable Steam-Chest Seat Milling-Machine.—Fig. 12 shows a machine built by Pedrick & Ayer, of Philadelphia, adapted to supersede the slow and expensive operation of cutting a

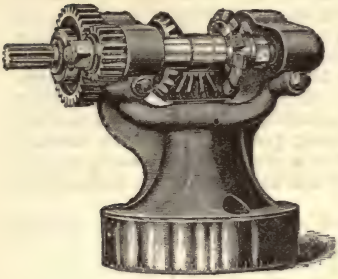

FIG. 10.—Angular attachment.

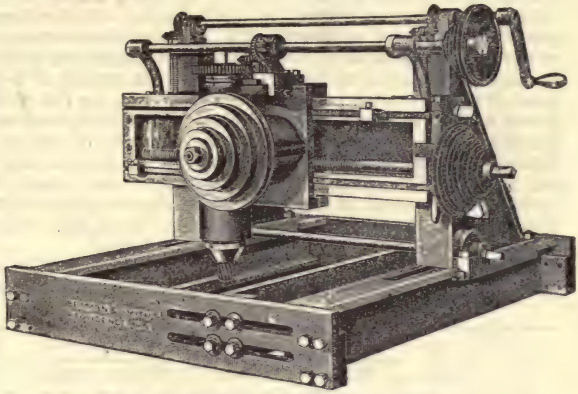

FIG. 11.—Cylinder-port milling-machine.

groove in the surfaces adjoining the steam-chest seat with hammer, chisel, and file. This machine is also adapted to the drilling either of new holes for studs or the drilling out of old

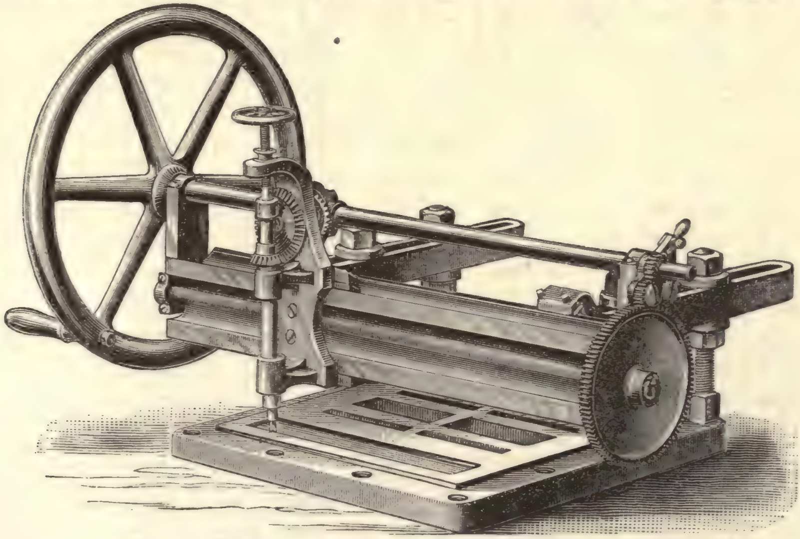

FIG. 12.—Steam-chest seat milling-machine.

studs when broken off. It is supported and adjusted to the surface to be grooved or milled by four studs, running through two hollow arms, which in turn support the Vs or slide. This slide carries a head containing a spindle, similar to a drill-press, and this head receives a transverse movement by means of the screw, as shown, the milling spindle being driven by béveled gears and a transverse shaft. The cutting or grooving is performed by a face-milling cutter inverted in the end of the spindle, and is fed up and down by means of a screw and small wheel, and when the proper depth for a cut is reached the horizontal movement of the spindle is prevented by means of a check-nut on the small screw. The sliding or tool head is fed in either direction by means of change feed-gears at the end of the screw.

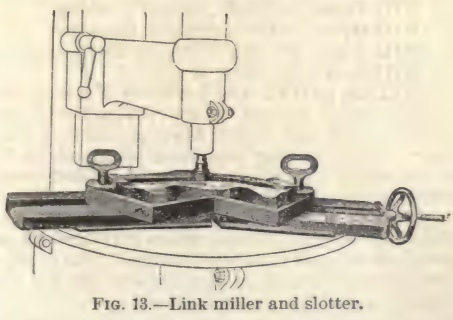

FIG. 13.—Link miller and slotter.

Leeds' Link Miller and Slotter.—This machine (Fig. 13), built by Pedrick & Ayer, of Philadelphia, is used as an attachment either to a heavy milling-machine or a strong drill-press. It will mill out links to any desired ra-

dius. It is designed on the principle that the apex of any angle will touch or describe all parts of a circle whose versed sine is equal to the perpendicular where the base is formed by the chord of the arc. It consists of a jointed frame having dovetailed slots running lengthwise to carry a second frame that has the link-blank secured in it. The second frame is actuated by the screw and hand-wheel and describes a circle, according to the angular position of the lower or jointed frame; flanges are cast on the bottom of the frame for the purpose of bolting down on the table or platen. In the center of the lower frame, at the center of the joint, is a bronze bushing that is set exactly under the center of the drill-press spindle; this serves as a lower support for a boring-bar and the shank of the milling-tool arbor. In practice it is found more convenient to drill a hole in one end of the link to be slotted, large enough for a boring-bar to pass through; then, by using a double-end cutter, the slot is cut out to nearly the finished size. The link is then moved along ⅜ or ½ in., and is cut through again until the stock is removed. A milling-cutter similar to a reamer is then used, and the slot is finished to the radius for which the link is set. With this attachment it is claimed that a link 20 in. long can be finished in about 4 hours.

Speed and Feed of Milling-Cutters.—The following table gives the speeds of milling-cutters adopted in American practice (see *Engineering*, December 12, 1890):

Diameter of mill.	Depth of cut.	Feed per revolution.	CUT ½ IN. WIDE.				CUT ½ IN. WIDE.				CUT 2 IN. WIDE.				CUT ¼ IN. WIDE.			
			Steel.		Cast iron.		Steel.		Cast iron.		Steel.		Cast iron.		Steel.		Cast iron.	
			Revolutions per min.	Feed per min.	Revolutions per min.	Feed per min.	Revolutions per min.	Feed per min.	Revolutions per min.	Feed per min.	Revolutions per min.	Feed per min.	Revolutions per min.	Feed per min.	Revolutions per min.	Feed per min.	Revolutions per min.	Feed per min.
½ in.	1/16	·009	490	4 7/16	600	5 3/8	400	3 5/8	460	4	300	2 11/16	400	3 4/5 Scale.	....	....	....	....
	½	·009	430	3 7/8	460	4	......	......	......	....	....	......	270	3	....	....	....	....
¾ in.	1/16	·010	320	3 1/2	400	4 7/16	260	2 7/8	300	3 5/16	200	2 3/16	260	4 1/2 Scale.	....	....	....	....
	¾	·010	270	2 15/16	300	3 5/16	......	......	......	....	....	......	180	4	....	....	....	....
1 in.	1/16	·014	245	3 7/16	300	4 5/16	200	2 13/16	230	6 1/2	150	2 1/8	200	6 Scale.	....	....	....	....
	1	·014	175	2 7/16	230	3 1/4	......	......	150	2 1/8	....	......	135	5	....	....	....	....
1½ in.	1/16	·016	160	2 9/16	200	3 3/16	130	2 1/16	160	5 1/2	100	1 5/8	130	5 Scale.	....	....	....	....
	1	·016	115	1 7/8	160	2 9/16	50	13/16	100	1 5/8	....	......	90	4	....	....	....	....
2 in.	1/16	·021	120	2 1/2	150	3 1/8	100	2 1/8	120	5	75	1 9/16	100	5 Scale.	70	1 1/2	80	4 1/2 Scale.
	1	·021	85	1 3/4	120	2 1/2	40	13/16	75	1 9/16	....	......	70	4	....	....	60	3 1/2
3 in.	1/16	·031	80	2 1/2	100	3 1/8	70	2 3/16	80	5	50	1 9/16	70	5 Scale.	45	1 1/8	55	4 1/2 Scale.
	1	·031	50	1 9/16	80	2 1/2	25	3/4	50	1 9/16	....	......	45	3 1/4	....	....	40	3
4 in.	1/16	·031	65	2	80	2 1/2	50	1 9/16	60	4 1/2	40	1 1/4	50	4 1/2 Scale.	35	1 1/8	40	4 Scale.
	1	·031	40	1 3/8	60	1 7/8	20	5/8	40	1 1/4	....	......	35	2 3/4	....	....	30	2 1/2
6 in.	1/16	·031	40	1 1/4	50	1 9/16	35	15/16	40	3 1/2	25	3/4	35	3 1/2 Scale.	20	5/8	30	3 Scale.
	1	·031	30	0 15/16	40	1 1/4	12	3/8	25	3/4	....	......	22	2	....	..	20	2
Surface speed per min......			45 ft. and 65 ft.		60 ft. and 80 ft.		20 ft. and 50 ft.		40 ft. and 60 ft		40 ft.		35 ft. and 50 ft.		36 ft.		30 ft. and 45 ft.	

NOTE.—When the work will not permit the above speeds, reduce the speed of cutter in preference to the feed.

Mill-Iron: see Rolls, Metal-Working.
Mill-Ore: see Ore-Crushing Machines.
Mill-Pug: see Clay-Working Machines.
Mill-Saw: see Saws, Wood.

MILLS, GOLD. *Gold-Milling Machinery.*—Auriferous ores are commonly worked by the amalgamation process. Very rich gold-ores are sometimes sold to the lead-smelters and their gold contents collected in the lead bullion; but the ores from which nearly all of the gold of the world, excluding that from placer-mines, is produced are of altogether too low grade to be treated in that manner. In the typical gold-mill the ore coming from the mine is dumped over a grizzly, and the coarse lumps crushed by means of a Blake, Dodge, or Gates crusher to convenient size, say, so as to pass a 1-in. ring. The crushed ore is fed by automatic feeders into wet-crushing stamp-batteries, where it is crushed to that degree of fineness necessary to free the particles of gold from the gangue. The stamp-batteries are lined with copper plates covered with mercury; and as the pulp inside the battery is splashed against these plates before being crushed fine enough to be thrown out through the slotted steel screen, which forms one side of the mortar, a part of the gold is amalgamated. When the ore is crushed fine enough to pass through the screen, it flows down over a table of the same width as the mortar, and 8 ft., 10 ft., or 12 ft. long, covered with copper plates coated with silver amalgam, by which

the particles of gold not already amalgamated within the mortar are caught. The pulp which has passed over the plates, always carrying a small amount of gold not practicable or economical to save, is called tailings, and is allowed to run away. The gold in ores, however, is not always free—that is, occurring in separate particles—but is sometimes contained in a mineral, occasionally in galena, but generally in pyrites. The gold thus contained can not be amalgamated, and other means are necessary for its recovery. For this purpose the first step is to save the auriferous mineral, and this is accomplished by concentrating the tailings from the amalgamating plates. As the tailings are generally very fine, in most cases exceeding 40 mesh, slime-washing machines are used exclusively for concentration in gold-mills. As it is only necessary to make one separation—that is, headings and tailings—Frue vanner's or another of the belt machines are admirably adapted for the purpose and are almost invariably used, although end bump-machines are employed in some mills. The pyritic concentrates thus made are usually rich enough to be shipped to the lead-smelters, and in many districts whence freight rates to a smelting center are low are disposed of in that manner. Another method of treating auriferous pyrites, and one in which great progress has been made during the past ten years, is by chlorination. In this process the ore is roasted oxidizingly for the elimination of the sulphur, after which it is subjected to the action of chlorine gas, in covered vats or barrels, whereby the gold is converted into chloride of gold, which is soluble in water. The chloride of gold having been dissolved, the filtrate is run to suitable tubs, where the gold is precipitated by hydrogen sulphide or ferrous sulphate. The fine precipitate is dried, and finally melted into bullion. Ores containing both gold and silver, such as those of the Comstock lode, are usually treated by the process of pan amalgamation (see SILVER-MILLS), but this process is seldom used for ores carrying gold alone.

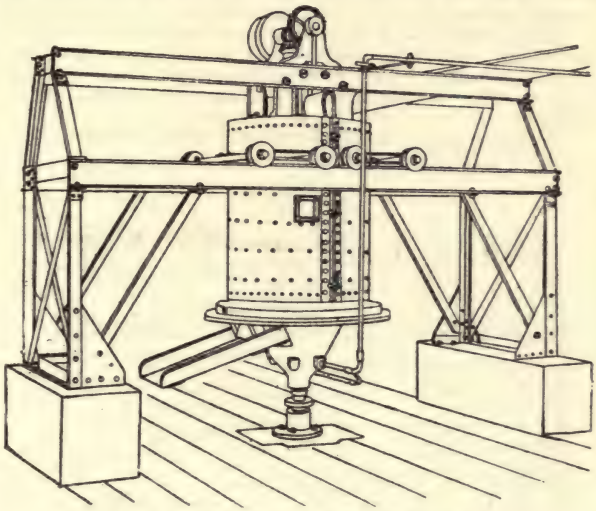

FIG. 1.—Jordan's centrifugal amalgamator.

The cost of gold-milling varies with the character of the ore, the equipment of the mill, the method of milling, etc. The lowest figure ever reached was at the mill of the Spanish Gold-Mining Co., Washington, Nevada County, Col.; there, in 1886, ore was milled at a cost of but 24·9 cents per ton. The ore consisted of about one third hard quartz, one third tough slate, and one third decomposed quartz and slate. The crushing machinery consisted of three 5-ft. Huntington mills and one 4-ft. mill, running at 60 revolutions per min., consuming 22 horse-power, and discharging through a No. 6 slot screen. In a 4-months' run, 19,402 tons of ore were crushed; the averaging cost of milling being, as before stated, 24·9 cents per ton, divided as follows: Labor, 9 cents; water, 3·6 cents; shoes, 2·9 cents; screens, 1·3 cents; dies, 1·7 cents; caps, scrapers, and bolts, ·2 cent; renewal of working parts, 2 cents; quicksilver (at $40 per flask), ·5 cent; oil for illumination and lubrication, ·2 cent; labor at rock-breaker, 2 cents; wear and tear of rock-breaker, ·5 cent; depreciation, 1 cent. Later the cost was further reduced to 20·8 cents per ton, of which 11·8 cents was for labor and 9 cents for supplies. The ore which was worked at this mill averaged only 65 cents per ton, and was actually mined and milled for 52 cents per ton, the mine being opened as a quarry and worked under extremely favorable circumstances. The foregoing figures are from statements by Mr. F. W. Bradley, the superintendent of the company. The Plymouth Consolidated Gold-Mining Co. milled ore in 1886 at an expense of 39 cents per ton, and saved and reduced the sulphurets at an additional expense of 17 cents per ton of ore. The Plumas-Eureka Mining Co. milled ore in 1888 at an expense of 58¾ cents per ton, and in the same year the cost at the Yuba and Hanks mills of the Sierra Butte Gold-Mining Co. was but 26¼ cents and 35 cents per ton, respectively. In Montana, in 1888, at the 60-stamp mill of the Montana Co., Limited, low grade gold-ore was crushed and amalgamated on plates, and the sulphurets concentrated on Frue vanner's at a cost of $1.13 per ton. At the large mill of the Alaska-Treadwell Gold-Mining Co., Douglas Island, Alaska, the cost of milling ore and concentrating sulphurets, for the year ending May 31, 1891, was 42·06 cents per ton, of which 19·4 cents was for labor and 22·66 cents for supplies. At the Golden Star mill (120 stamps) of the Homestake Mining Co., at Lead City, South Dakota, the cost of milling in 1887–'88 was, according to Mr. H. O. Hofman, 82·92 cents per ton. The best practice in gold-milling in this country at the present time is undoubtedly that of California. McDermott and Duffield state that, on a considerable variety of gold-ores in that State, the percentage of gold saved averages

from 80 to 85 per cent, and careful daily tests in some of the best gold-mills using concentrators show from 85 to 90 per cent.

The largest chlorination works in the world are at the famous Mount Morgan mine in New Zealand, where a modification of the Newberry-Vantin process of barrel chlorination is used. The ore averaged, as worked, 5 oz. gold per ton, and 1,800 tons were treated per week, while the tailings are said to contain only 3 dwt. gold per ton, which, if correct, represents a saving of 97 per cent. The cost of the process on this large scale is given as $7.50 per ton. Mr. A. Thies states that the cost of chlorinating at the Haile Mine, Lancaster County, North Carolina, is $4.62½ per ton of roasted ore, divided as follows: Roasting, $2.62½; chlorinating (power, 12½ cents; labor, 95 cents; chemicals, 60 cents), $1.67½; ferrous sulphate for precipitating, 12½ cents; repairs and wear, 20 cents; total, $4.62½. This is equivalent to $3.47 per ton of raw pyrites. No figures have been published concerning the cost of chlorination in the Black Hills, but the Haile figures have probably been exceeded, owing to the larger tonnage worked, notwithstanding the higher cost of labor, fuel, and supplies.

AMALGAMATORS.—A large variety of mechanical amalgamators, to take the place of copper plates, have been invented, but none have come into very general use. These machines are generally pans or cylinders in which the pulp is rotated with mercury, the object being to bring the particles of gold in more intimate contact with the mercury than on the plates.

Jordan's Centrifugal Amalgamator (Figs. 1, 2) consists of a series of shallow dishes, attached one below another to a central revolving shaft, and inclosed in a fixed circular casing. Secured to the inner side of the casing, and alternating with the dishes, are slightly inclined shelves, also amalgamated. The pulp fed into the amalgamator enters the first dish, in which it is revolved until impelled by the centrifugal motion over the edge of a dish. It then falls on one of the shelves and is thus conveyed to the center of the second dish, there to undergo similar treatment. This is repeated to the end of the series, where the tailings escape. The free gold and silver contained in the pulp are arrested by the amalgamated dishes and shelves, which are scraped at suitable intervals and the amalgam retorted.

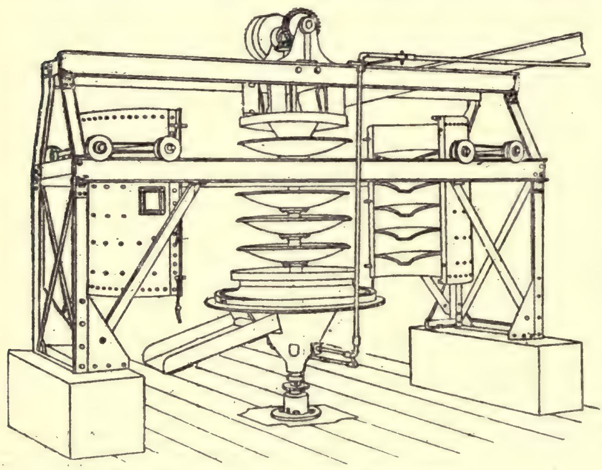

FIG. 2.—Jordan's centrifugal amalgamator.

The Cook Amalgamator (Fig. 3) consists of a horizontal iron cylinder A, with an interior spiral rib, rotated about 30 times per min. The spirals e form a channel 40 ft. long, which divide the material and keep it divided all the way through the cylinder. The rotating action spreads the pulp and subjects it to a rolling motion in the water, the gangue going ahead of mineral ⅓ of the distance over amalgamating surface E, and ⅔ over non-amalgamating surface e, which always holds enough mercury to coat or amalgamate free mineral, making the whole distance amalgamating with only ⅓ amalgamating surface. The mineral is separated from the gangue, amalgamated and collected into little bunches of amalgam in cylinder, and as amalgam passes to the tables and wells. The tables have a continuous amalgamating surface to the mercury-wells where the amalgam is collected. Gate h spreads the water, etc., which passes under it and flows up from gate-well and is thrown down by splash-plate h^1 on table H, thence on to tailings indicator J and discharge-spout o. The tailing-indicator consists of two amalgamating plates on which the tailings drop; these plates indicate, collect, and deposit, it is said, in the well any possible loss of amalgam or mercury from the machine. According to the

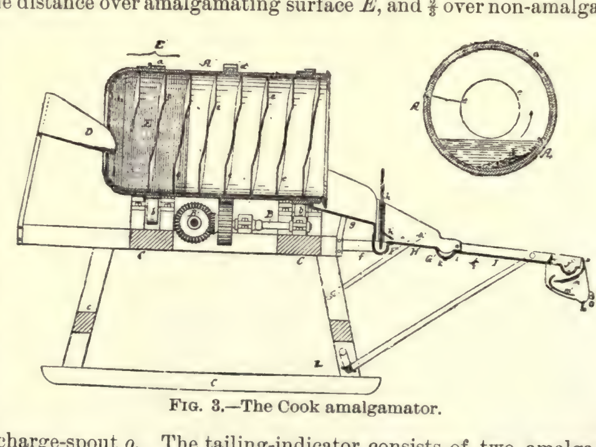

FIG. 3.—The Cook amalgamator.

manufacturers, a cylinder 7 ft. long and 2 ft. in diameter will treat the pulp of from 5 to 10 stamps. It requires 18 gals. of water per min., and ¼ horse-power.

Chlorination Machinery.—The chlorination barrel used at the Golden Reward Chlorination Works, Deadwood, S. D., the methods employed at which represent the best American practice in barrel chlorination, is thus described by Mr. John E. Rothwell in the *Engineering and Mining Journal*, vol. li, 165, 166: The chlorination barrel used in these works is made to serve at the same time as the washing and leaching vessel, by placing a supporting diaphragm to form the chord of an arc of the circle of the barrel. The diaphragm, or filter as it is called, is made up of corrugated plates, and perforated with holes every 4 or 6 in. square. These plates are supported on segments which are bolted to the shell of the barrel; on top of the corrugated plates is placed the filtering medium, an open-woven asbestos cloth. Over this is placed an open grating, and the whole is held in place by cross-pieces, the ends of which rest under straps bolted to the inside shell; in this way, while the whole is rigidly held in place, it is very easily and quickly removed when the changing of the asbestos cloth becomes necessary. Two valves on each end of the barrel above and below the filter are for the inlet and outlet of the wash-water and solution, respectively. The barrel is charged by first filling the space under the filter with water, which at the same time is allowed to pass through the filtering medium and wash it; then the required quantity of water is put in above the filter. There are now two methods of charging the pulp and the chemicals (lime chloride and sulphuric acid). In one, the lime is so placed in the ore charge in the hopper over the barrel that it goes in with the ore and is completely buried with it; the acid can then be added with very little danger of generating any gas before the plate on the charging hole can be put on and securely fastened. The other way, which seems to be still better, is to pour the acid first into the water, through which it sinks in a mass to the bottom and does not mix; the ore is then let in, and the lime added the last. The chances of wasting any gas are much less than in the first method. On the first revolution of the barrel the gas is immediately liberated, and creates considerable pressure. After the chlorination is complete the barrel is stopped, so that the filter assumes a horizontal position; the hose is attached to one of the outlet pipes and conducts the solution to the reservoir tank. A hose is also attached to the inlet pipe and water is pumped in under pressure, and the leaching commences. The air in the top part of the barrel is compressed and forms an elastic cushion, which gives the wash-water perfect freedom to circulate evenly over the whole surface of the charge, and wash every portion of it thoroughly and with the smallest quantity of water possible. The length of time required to do the leaching varies with the leaching quality of the ore treated—charges having been leached in 40 min. with a pressure of from 30 lbs. to 40 lbs. per sq. in. With higher pressures the time can be materially shortened. In order to facilitate the leaching of charges carrying an excess of slimes, a valve placed in the head of the barrel, on a level with the surface of the pulp, is opened just after the barrel is stopped, and the dust and slime which remain in suspension are run off into an outside washing filter-press, where it can be treated separately.

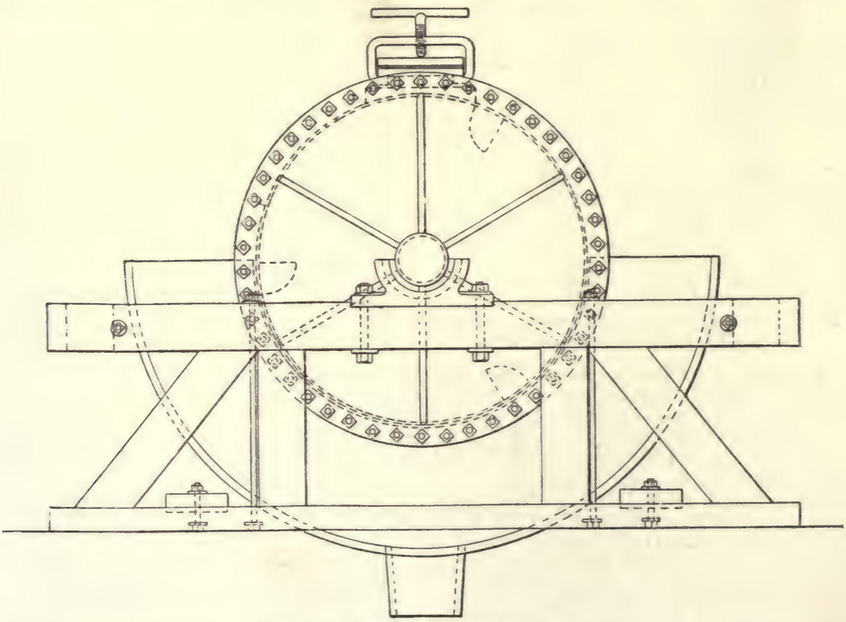

Fig. 4.—The Thies chlorinating barrel.

The tailings are discharged into a car which will hold the whole charge of ore and water, and then run out; or, if water is abundant, they are discharged into a sluice and washed away.

The amount of water required for leaching is about 120 gals. per ton more than the quantity used in the barrel for chlorination, which is about 100 gals. per ton. In order to get a concentrated solution for after-treatment, to reduce the amount of solution to be treated, and to save water, a tank is placed above the barrel, and when the richest of the solution and wash-water has run into the reservoir tank the discharge hose is connected with the pipe leading to the upper tank, and the washing is finished into it. The solution collected in this way is used in the next following charge in the barrel; the quantity of solution to be precipitated is thus reduced to about 120 gals. per ton of ore treated. One man and a helper are able to take care of three barrels—that is, to look after the charging, leaching, and discharging. If the tailings are sluiced out, they can also attend to it; but where they have to be trammed out, one more man is necessary.

The Thies Chlorinating Barrel (Fig. 4) is a lead-lined iron cylinder, 40 in. in diameter by 60 in. long, provided with suitable journals and driving-pulleys, and with a charging door and test-valve. The capacity of a cylinder of this size is from 1 to 1¼ tons of roasted ore. It is designed to make about 15 revolutions per min. Before charging with roasted ore, sufficient water is put in the barrel to make an easy-flowing pulp; from 100 to 125 gals. are used in the 1-ton barrel. If the ore is pure pyrite from 10 to 15 lbs. of chloride of lime and from 15 to 25 lbs. of sulphuric acid are sufficient to convert all the base metals as well as the gold into chlorides. If the ore contains copper, double the amount of chemicals will be required, and it is considered preferable to divide the chemicals into two portions and add the second after the barrel has been rotated for three or four hours. The time required for the chlorination of a charge of ore is from four to six hours. If at the end of that time the existence of free chlorine in the barrel is shown by means of the test-valve, the ore is thrown direct on the filter and leached until there is no reaction with ferrous sulphate. The Thies filters are lead-lined vats 6 × 8 ft. and 18 in. deep, with a fall of 1 in. toward the outflow. Their bottoms are covered with perforated glazed tile, on which rests a graded filter-bed of gravel, topped off with clean river sand, making a total depth of about 5 in. The thickness of pulp spread on a filter from one ton of roasted ore averages about 4 in., and the time required to leach this ore averages from two to three hours. The precipitating tanks are 8 ft. in diameter and 3 ft. deep. Vats of this size hold solutions from 3 tons of roasted ore.

The Pollok Chlorinating Barrel (Fig. 5) consists of a light steel cylinder supported on trunnions and lined with a coating of gutta-percha about ⅛ in. thick, on which chlorine has no action. At one end of the cylinder is a valve for charging and discharging. The cylinders are charged as follows: first, 80 lbs. of nitre is dropped in, then 2 tons of ore, and lastly, 60 lbs. of bleaching powder. The charging door is then closed and sealed, and water is forced into the barrel until the pressure rises from 70 to 100 lbs. The cylinder is then revolved, mixing the ore with the bleaching powder and nitre cake, and the chlorine thus evolved goes into solution in the water, and, acting on the gold, converts it into chloride. The cylinder is revolved from an hour to an hour and a half, when its contents are discharged on a filter-bed placed below. The waste chlorine is blown off and largely recovered by being passed through slaked lime and thus absorbed. The filter is made of steel wire lined with India-rubber. The charge, after being decanted on the filter-bed, is filtered, and the chlorine liquor containing the gold is drawn off by a specially designed vacuum-pump, by which it is pumped into the precipitating tank, where the gold is precipitated by adding ferrous sulphate. The precipitating tank has a conical-shaped bottom, on which the gold precipitate settles. As soon as the liquor has become clear it is run off, and the gold is removed and melted with borax into bars.

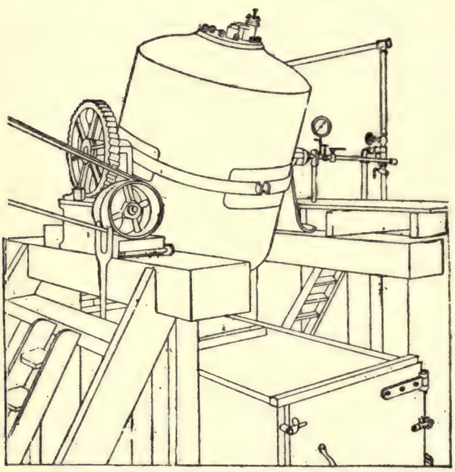

FIG. 5.—The Pollok chlorinating barrel.

Works for reference: *The Metallurgy of Gold*, by Manuel Eissler, 1891; *The Metallurgy of Silver, Gold, and Mercury in the United States*, by T. Egleston, vol. ii, 1890; *Losses in Gold Amalgamation, with Notes on the Concentration of Gold and Silver Ores*, by Walter McDermott and P. W. Duffield, 1890; *Gold, its Occurrence and Extraction*, by A. G. Lock, 1882; *Practical Gold-Mining*, by C. G. W. Lock, 1889; *Notes on the Treatment of Gold Ores*, by F. O'Driscoll, 1889; *Leaching of Gold and Silver Ores*, by C. H. Aaron, 1881; Notes on the Hydro-metallurgy of Gold and Silver, by C. H. Aaron, *Annual Report of the State Mineralogist of California*, 1888; Gold-Milling in the Black Hills, by H. O. Hofman, *Transactions American Institute of Mining Engineers*, vol. xvii; The Thies Process of treating Low-Grade Auriferous Sulphides at the Haile Mine, South Carolina, by A. Thies and William B. Phillips, ibid., xix, 601; The Practical Chlorination of Gold Ores and the Precipitation of Gold from Solution, by John E. Rothwell, *Engineering and Mining Journal*, vol. li, 165; Notes on Gold-Milling, by C. H. Aaron, vol. xlviii, August 10 and 17, 1889.

MILLS, SILVER. Silver-ores are worked by one of three ways—amalgamation, lixiviation, and smelting. The selection of the process for treating any particular ore is a question of dollars and cents, and no general rules can be laid down. In Colorado, silver-ores are treated almost exclusively by smelting. There are three great smelting centers in that State and an abundance of silver-lead ore, and, freight rates being comparatively low, siliceous silver-ores even of ordinary grade can be smelted cheaper than they can be milled. On the other hand, the gold-silver ores of the Comstock and the silver ores of Butte, Phillipsburg, and Tuscarora are milled by the amalgamation process, while the lixiviation process is used at Park City, Utah, as well as amalgamation, and at several places in Mexico. In the amalgamation process the silver contents of an ore are recovered by amalgamating them with mercury. In the lixiviation process they are leached out with certain chemicals and the silver precipitated from the solution by other chemicals. In amalgamation, silver-ores are classed as free-milling, or those in which the silver exists in the form of a mineral which can be amalgamated directly, and non-free-milling, which require a preliminary roasting to convert the silver minerals into such form that they can be amalgamated. Siliceous ores containing native silver, or silver chloride, bromide, or iodide, are typical free-milling ores, while ores in which the silver is carried by sulphides of the base metals constitute the class for which a preliminary roasting is necessary.

Free-milling ores are worked in wet-crushing mills, the customary arrangement of which is as follows: The ore brought in by cars at the top of the mill is dumped over an inclined grizzly or screen and rolls on to the crusher floor. All the small pieces pass through the screen or grizzly into the ore bins underneath. The coarse rock is shoveled into the crusher from the floor, which is on a level with its receiving jaws, and is crushed to the size of walnuts, falling into the ore-bins, whence it passes into the automatic stamp-feeders through inclined chutes controlled by ore-gates. The automatic feeders, being kept full, supply the stamps uniformly and as fast as required.

The finely stamped ore suspended in water, and known technically as pulp, flows into large settling-tanks, where excess of water is drawn off. The thick pulp remaining is shoveled in regular charges into a row of amalgamating pans, in which it is worked several hours, first with salt, blue-stone, and other chemicals, then with additions of quicksilver. The contents of the pans are run into large settlers placed below and in front of the pans, in which the pulp is thinned by additions of water and gentle agitation, and all the quicksilver with precious metals in the form of amalgam settles to the bottom. The pulp is gradually run off from the settlers and flows to waste. The amalgam is strained from the excess of quicksilver, retorted to drive off the remaining quicksilver, and the resulting mass of silver and gold melted into bars.

Sometimes values carried in base minerals which will not yield to the above process are caught by concentrators (usually Frue vanners or one of the similar belt machines), which receive the waste pulp from the settlers. Generally three pans are supplied with five stamps in this process, so that a 10-stamp mill would require six pans and three settlers. On some ores two pans are sufficient. The quicksilver is usually elevated and distributed throughout the mill by a special elevator. This process was devised for treating the ores of the Comstock lode, on which account it is frequently known as the Washoe process, and after many years of study and experiment it was perfected there during the ten years between 1870 and 1880. Mr. A. D. Hodges, Jr., in his paper, Amalgamation at the Comstock Lode (*Trans. A. I. M. E.*, vol. xix, p. 195), gives an interesting account of its development, and a description of the methods and apparatus finally adopted. Since that time the process has remained practically unchanged.

The old process of barrel amalgamation is no longer used in this country, having been entirely replaced by pan amalgamation. Where the ore is base and needs a desulphurizing and chloridizing roasting before the amalgamation can be successfully carried on, a dry-crushing mill (Fig. 1) is used, of which the general arrangement is as follows: After passing the rock-breaker the ore is dried either in a revolving drier or by means of a kiln, and the dried ore is fed by automatic feeders to the stamps. The pulverized ore from the stamps is raised to a bin in the upper part of the mill by a belt elevator (see Ore-Dressing Machinery), whence it is fed into a suitable roasting-furnace. In the furnace the ore, with the addition of common salt, is desulphurized and chloridized, the silver minerals of the ore being converted into silver chloride and thus prepared for the pans and settlers. After roasting, the ore is spread out on a cooling floor and is taken as required to the pans. Amalgamation follows on the same plan as in the wet-crushing mill. In some cases it is found desirable to concentrate the ore before amalgamating in wet-crushing mills, this combination never being made in a dry-crushing mill for obvious reasons. Ores subjected to this double treatment might be classed as semi-free milling, containing a portion of their silver value in base sulphides and a portion in such form that it can be recovered by raw amalgamation. In such combination-mills, slime-washing machines, buddles, bumping-tables, or vanners, are interposed between the stamp-batteries and the settling-tanks. The silver-bearing base metals are thus concentrated and smelted, while the tailings run to the settling-tanks and are then treated in the usual manner. This process was introduced quite successfully at the mill of the Combination Mining and Milling Co., Black Pine, Deer Lodge County, Montana, according to C. W. Goodale and W. Akers (*Trans. A. I. M. E.*, vol. xviii, p. 242). The ore was quartzose with galena, lead, copper, zinc, and a little sulphur, a considerable proportion of the silver being carried by the base minerals. The mill had 10 stamps, the pulp from which was passed over four Frue vanners. The tailings

from the latter were settled and amalgamated. During the year ending May 31, 1889, 9,061 tons of ore, of an average assay of 22·67 oz. silver per ton, were crushed. There were produced 541 tons of concentrates, averaging 136 oz. silver per ton, which were sold to the lead-

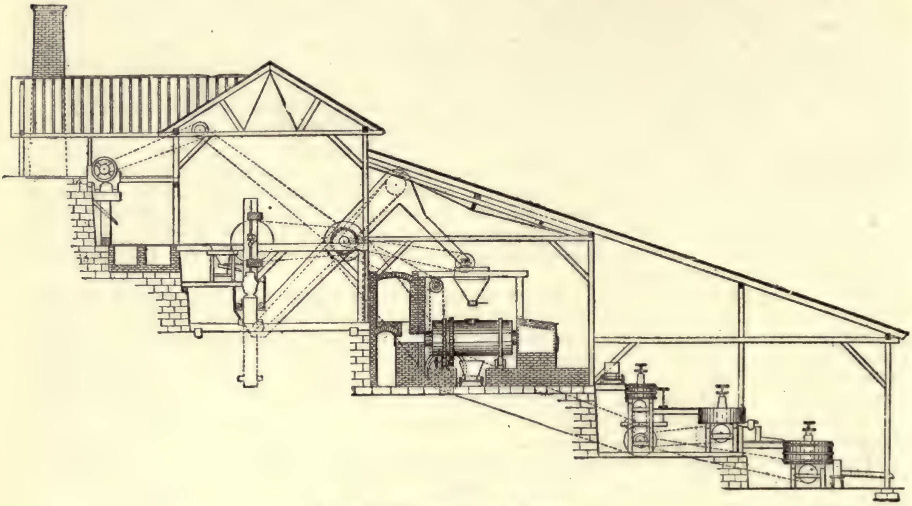

FIG. 1.—Dry-crushing silver mill.

smelters. The total saving by concentration and amalgamation was 83·45 per cent, and the cost of the combined process $4.35 per ton.

The Boss continuous process is a comparatively recent improvement upon the system of pan amalgamation. In this the pulp flows directly from the stamp-batteries to the pans, and the use of settling-tanks is done away with. The ore coming to the mill, it is dumped over grizzlies and passes through rock-breaker and ore-feeders into the batteries in the usual manner. The pulp from the batteries is then conveyed in pipes to the special grinding-pans placed immediately below and in front of batteries. In these pans, all grinding of the pulp is done, the product of ten stamps passing through two in succession. By their use the capacity of the stamps is increased, as coarser screens can be used in the batteries, and finer grinding is done in the pans. If the pulp needs chemical treatment before amalgamation it is run from the grinding-pans into a chemical mixer, where the proper chemicals are added, and thence runs to the first amalgamating pan of a series placed in line. From the first pan the pulp flows continuously through the pans and settlers, they all being connected together by pipes near the tops of their sides, and one overflowing into the other through the line. The amalgamating pans are charged with quicksilver by means of pipes leading from the distributing tank, and the amalgam is drawn off through pipes to the strainers in front of pans. Here a quicksilver elevator lifts the strained quicksilver back to the distributing tank, and all handling of that metal is thus avoided.

The pans and settlers are all placed upon the same frame and upon the same level, and each is driven by means of gears brought into action by a friction-clutch fitted to the gear on the main-line shaft. This arrangement, peculiar to the Boss process mill, is one of the leading features in the mechanical construction of this system. By it the pans and settlers are brought down close to their main driving-shaft, and receive their motion directly from it without the intervention of belts, tighteners, counter-shafts, and high-pan frames, as in the old-style mill. Each pan and settler being thus provided with a separate clutch, any pan or settler, or any number of either, can be stopped independently of the others, in case of accident or for cleaning-out purposes. In order to secure the continuous flow of the pulp through the line when one or more pans or settlers are stopped, steam siphons are provided for carrying the pulp past them and cutting out for repairs or cleaning.

In amalgamation by this method, the pulp comes to the pans in even and regular proportions of sand and slimes. It all necessarily passes through the series of pans and settlers, and receives a uniform treatment. This uniformity and regularity, it is claimed, can not be attained when the pulp is settled in tanks and worked by charges. The amount of treatment the pulp receives in its passage is proportionate to the size of stream that flows into the pans; and the amount of treatment may be increased by decreasing the inflow, or *vice versa*. It is also claimed that the loss of quicksilver is less in this than in the ordinary process of pan-amalgamation.

The process of lixiviation for the treatment of silver-ores was first introduced in this country, or rather in Mexico, by Mr. Ottokar Hofmann in 1868, the Patera process being used. During the past ten years great progress has been made in this direction, the decade having been marked by the invention of the Russell process. The general process of silver lixiviation consists in roasting the ore to convert its silver contents into the form of chloride,

then dissolving the chloride of silver in hyposulphite of sodium, precipitating the silver as sulphide with sodium or calcium polysulphide, and refining the silver sulphide to bullion. The ore is first crushed by a rock-breaker, and then pulverized by stamps or rolls, the former being more generally employed than the latter; although rolls have advocates. The crushed ore is subjected to a chloridizing roasting, as in amalgamation, the amount of salt used varying with the character of the ore, ranging from 4 to 10 per cent, or thereabouts. The roasted ore, after leaving the furnace, is spread on the cooling-floor, moistened with water, and charged into vats in lots of from 8 to 15 tons. These vats, which constitute the leaching-tubs, are provided with a central discharge, around which a filter bottom is arranged in the shape of a very flat funnel. The filter-cloth is kept in place by ropes driven into grooves around the discharge-hole and the inner periphery of the vat near the filter bottom. The vat is furthermore provided with an outlet under the filter bottom, and has a slight inclination toward this outlet.

The charge of roasted ore is leached with water, to remove the soluble base-metal salts. Water does not dissolve silver chloride, but a concentrated solution of base-metal chlorides does, and therefore it is advisable not to make the leaching-vats too deep, as otherwise a too concentrated base-metal solution is produced by the water in descending through a thick layer of ore. The base-metal leaching is completed when a few drops of calcium polysulphide poured into some of the outflowing solution does not produce a precipitate. This part of the process takes, according to the character of the ore, from 4 to 8 and 10 hours. The base-metal salts being removed, a stream of diluted solution of sodium hyposulphite is allowed to enter on the top of the ore. Sodium hyposulphite readily dissolves silver chloride. When the outflowing solution shows indications of silver, which also can be determined by an addition of a few drops of calcium polysulphide, the stream is conveyed to special tanks (the precipitating tanks), in which the silver is precipitated as silver sulphide by an addition of calcium polysulphide. To facilitate and hasten the settling of the silver precipitates, the precipitation-tanks are provided with stirrers, by which the solution can be vigorously agitated. After precipitation, the sodium hyposulphite solution is again in its original condition, and is therefore, after the precipitate has settled, decanted from the latter into tanks placed on a lower level. From these tanks the clear solution is pumped up to storage-tanks, and is ready to be used again. When all the soluble silver is extracted, the tailings are sluiced out through the central discharge, and the tank is ready for another charge of ore. The time required for silver leaching varies according to the character of the ore from 8 hours to 2 and 3 days. When enough silver precipitates have accumulated on the bottom of the precipitating tanks, they are drawn off and strained through a filter-press, or through properly arranged filters made of cotton cloth. The precipitate is then charged into a small reverberatory furnace and the sulphur burned off. The roasted precipitate is melted with lead in a cupelling furnace and refined. The wear and tear of a lixiviation plant is insignificant. The base-metal salts penetrating the wood of the vats prevent them from decay and preserve them for many years.

Hofmann's system of trough lixiviation is a continuous one. The roasted ore is fed mechanically first into a stream of water, which rapidly moves in a triangular trough, for the removal of the base-metal salts. The pulp drops into settling-vats in which the washed ore accumulates. The washed ore is then sluiced out with a stream of sodium hyposulphite solution and the pulp conveyed through a triangular trough to another set of settling-tanks. In these tanks the mineral drops desilverized as tailings, while the silver is in solution. Base-metal salts and silver chloride dissolve almost instantly if the ore is charged into a rapid-moving stream of the respective solvent. The chemical process of this method is the same as in tank lixiviation, but the time of leaching is said to be shortened, and the manipulations are much simpler and more labor-saving. This method is especially adapted for larger works, and for ore which on account of lead requires a long leaching. A 50-ton lixiviation-mill designed for this process is shown, in elevation, in Fig. 2.

The Russell process is a modification of the ordinary system of tank-lixiviation or Patera process, in which a certain proportion of cuprous sulphate is added to the solution of sodium hyposulphite, constituting the lixiviant. This process has been carried to a high degree of perfection at the Marsac mill of the Daly Mining Co., at Park City, Utah. With very many classes of ore an additional amount of silver it is claimed can be extracted by means of this extra solution.

The cost of milling silver-ores varies greatly with the locality and the character of the ore. In 1876 the expense at the best-designed mills on the Comstock lode had been reduced to \$2.47½ per ton, and at the present time figures are probably lower; this ore is, however, perfectly free-milling. The cost per ton at the mills (amalgamation) of the Granite Mountain Mining Co., Phillipsburg, Mont., in 1890 was \$10.182, divided as follows: Labor—superintendence, ·284; engineers, ·159; firemen, ·099; crusher-men, ·122; roaster-men, ·319; drier-men, ·160; battery-men and helpers, ·463; cooling-room, ·250; pan-men and helpers, ·418; retort-men, ·046; assaying, ·093; watchmen, ·055; millwrights, ·113; repairing, ·043; sundry labor, ·715; total, \$3·339. Supplies—fuel, 1·639; castings, ·579; salt, 2·550; quicksilver, ·970; blue-stone, 144; lye, ·029; other chemicals, ·038; belting, ·022; lubricating, ·066; illuminants, .031; sundry supplies, ·430; total, \$6·498. Miscellaneous—tramming, ·120; water, ·096; blacksmithing, ·129; total, \$0·345. The amount of ore crushed was 63.529 tons wet, or 60.212 tons dry; amount of salt used, 9.379 tons; average assay of ore, 70·94 ounces silver per ton; average percentage of saving, 92·17. The salt and ore were mixed before crushing.

The cost in one of the three mills belonging to the company was but \$9.14, the average being raised by the other two.

The cost of milling at the works of the (amalgamation) Elkhorn Mining Co., Elkhorn, Jefferson County, Montana, in 1890, was $8.73 per ton, divided as follows: Superintendence, 47.80 cents; engineer, 26·41; crusher-man, 19·74; drier-men, 19·95; battery-men, 25·85; roaster-men, 23·24; cooling-floor men, 19·25; car-men, 37·52; amalgamators, 25·99; pan-helper, laborer, 02·49; melter, 01·90; assayer (proportion), 09·78; storekeeper, 05·59; repairs, 05·32; mechanics (proportion), 27·54; millwright, 06.64; teams and laborers, 32·18; watchman, 09·99; tailings, storage, 01·71; office (proportion), 08·25; chemicals, 10·64; lubricants, 05·79; illuminants, 01·24; quicksilver, 29·56; salt, 173·22; fuel, 165·70; freights, 11·80; castings, 48·33; other supplies, 15·14; general expense, 37·17; total, 873·01. The amount of ore

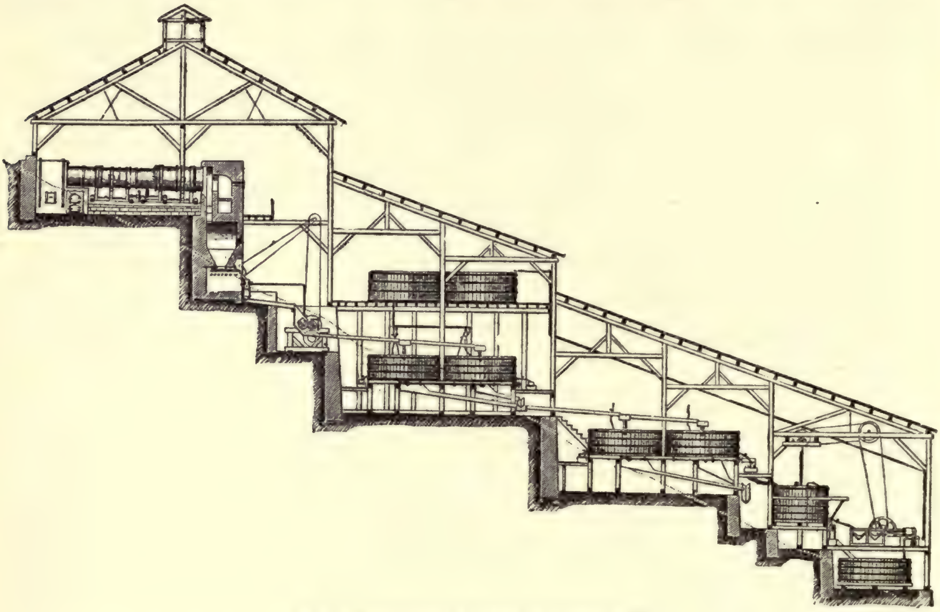

FIG. 2.—Hofmann's 50-ton lixiviation-mill.

crushed was 9,163 tons; amount of salt used, 990 tons; average assay of ore, 45·5 oz. silver; average assay of tailing, 6 oz.; percentage of silver saved, 86·83.

The Ontario and Daly mills, at Park City, Utah, furnish an interesting comparison, as at the former the ore is worked by amalgamation and at the latter by the Russell process of lixiviation, the ores being very similar in character. The cost per ton at the Ontario in 1890 was $9.08, 24,450 tons of ore being reduced. The average assay of the ore was 44·96 oz. silver per ton; average assay of tailings, 4·45 oz. per ton; percentage of silver saved, 90·03. In the same year 20,795 tons of ore were milled by the Daly Mining Co., at an expense of $6.38 per ton, 88·77 per cent of the silver being saved.

Mr. W. A. Wilson, superintendent of the Daly (Marsac) mill, in the *Engineering and Mining Journal*, vol. l, p. 444, gives the following items of comparison at these two mills:

	Ontario.	Marsac.
Water used per ton of ore, cub. ft.	400	56
Quicksilver or chemicals, per ton	$1 10	$0 64
Wrought and cast iron consumed per ton ... lbs.	5·5	·05
Power for driving pans and handling solutions, h. p.	108	1
Weight of ore treated per week ... tons	531	503
Fineness of crushing, mesh of screen	26	20
Rate of roasting per furnace per day ... tons	35·9	68·3
Per cent of salt used in roasting	38·8	9
Weight of each charge to pans and vats ... tons	1·3	72
Temperature in pans and vats	160° F.	81° F.
Labor on pans, vats, and product shipment	$0·445	$0 335
Chemicals and quicksilver in use	$14,600	$385
Fineness of product, silver, thousandths	440	305
Fineness of product, gold, thousandths	·26	·23
Baseness of product, copper, thousandths	560	116

The percentage of silver recovered in the Daly mill has reached as high as 92·2 per cent.

ORE-DRIERS.—*The revolving ore-drier*, which is generally used for drying ores in dry-crushing silver-mills, is a long cast-iron cylinder with a stationary fire-box at one end and a stationary flue at the other, the flames drawing through the cylinder as in the Brückner,

Hofmann, and Howell-White roasting-furnaces, although, of course, only a moderate heat is used. This drier, together with the shelf-drier, has entirely replaced the old boiler-iron floor-drier. The revolving cylinder is usually made in several sections for convenience of handling, having two tracks or tires on which it rotates, supported by rollers underneath. The motion is transmitted through gearing and pulleys. The cylinder is of larger diameter at the fire end than at the flue end, and ore from the rock-breaker is fed in at the smaller end. The cylinder's axis is placed horizontally, but owing to its conical form the ore must travel gradually toward the fire at the larger end. Shelves or wings arranged spirally inside raise the ore and shower it through the flames, assisting to quickly and thoroughly dry it. The size of the drier, as commonly used, is 44 in. diameter at the large end, 36 in. diameter at the small end, and 18 ft. long. Its capacity is 30 to 40 tons per 24 hours. It requires about 1,100 fire-bricks for lining this drier, and about 12,000 common bricks for a stack about 40 ft. high.

The Shelf-Drying Kiln consists of a number of inclined shelves, which are arranged zigzag above each other in a vertical shaft, having openings or slits where they meet, on which the ore rests in a stratum, the thickness of which is governed by the width of the slits and the inclination of the shelves. If a portion of the charge is removed at the end of the bottom shelf a sliding motion of the ore takes place on all shelves above, and the top shelf is replenished from a hopper set over it. It will be seen that the shaft is divided by the shelves into a number of triangular prismatic spaces. Through these the hot gases from a fireplace are made to circulate, each space communicating with the next one by a flue arranged in the side-wall of the shaft. These flues being located on alternate sides of the shaft, a continuous passage is formed through the whole structure. The kiln is 21 ft. high from the discharge floor to the top of the feed-hopper; the shelves are 2 ft. 4 in. wide and 5 ft. long, inclined at an angle of 38°. The stack should not rise more than 30 ft. above the top of the kiln. A double kiln requires a draft area of 3 sq. ft., and has a capacity of from 30 to 50 tons per 24 hours. The quantity of brick required for a double kiln is 30,000, and of iron 25,000 lbs.

Hot-Ore Coolers.—*Hofmann's Ore-Cooling Apparatus* (Fig. 3) consists of a square cast-iron tube *M*, 20 in. long, with lateral flanges, by means of which it is supported on a wooden frame over a trough. Inside the tube and opposite each other water-spouts are so arranged that the entering water forms sheets, not sprays, which perfectly close the tube. At the line where the opposite sheets of water meet, the water drops straight down. The hot ore in striking the water is immediately carried below the sheets of water, and is so quickly enwrapped in it that but little dust is formed. The ore and water passing downward from the tub drops into the trough, which has an inclination of 1¼ in. to 1 ft., and flows to the lump-mash machine or the leaching-trough. By this apparatus cooling-floor manipulation is avoided, and the temperature of the water used for base-metal leaching is increased by the waste heat of the ore. The mashing-machine consists of a set of Cornish rolls for breaking the lumps of ore which may have formed during the roasting. Before the pulp enters between the rolls it passes a No. 8 or No. 10 copper-wire screen. The screen has an inclination of 45°. The water and finer material pass through, while the coarser slides between the rolls, aided by an extra spray of water. The screen and the rolls discharge into the same trough, which leads to the base-metal department.

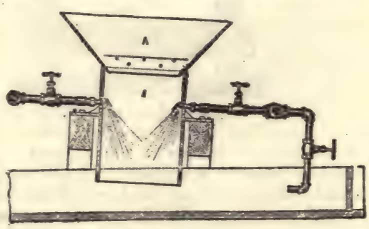

Fig. 3.—Hot-ore cooler.

Elevators.—*Ore-Elevators* (see Ore-Dressing Machinery).

The Quicksilver Elevator is much the same in form as the ordinary belt elevators, but the elevator-cups are made of Russia iron, and of a peculiar flask-shape, especially adapted to carrying quicksilver. The lower pulley and bearings are carried by a cast-iron boot, to which, and extending up to and around the upper pulley, is attached a wooden casing, which is to be made perfectly tight on the lower side and joints, to avoid a possible loss of quicksilver. This casing is preferably made of iron. The upper tank receives all the quicksilver and is made of cast iron. At the bottom a pipe leads off, and from this other pipes distribute the quicksilver to stamps, pans, and settlers, as may be desired.

Amalgamating Machinery.—*M. P. Boss's Special Grinding-Pan*, used for grinding the pulp as it comes from the battery in the Boss continuous process, is a solid, shallow cast-iron pan, 4 ft. in diameter, having solid ring shoes and dies slotted for a short distance from their inner edges to better admit the pulp between them. The pulp is introduced at the center of the pan; and, as a joint is made with a rubber gasket between the shoe-ring and muller-plate, it is all obliged to pass between the shoe and die before being discharged.

M. P. Boss's Standard Amalgamating Pan (Figs. 4 and 5) is similar to the pans used in the Washoe process, but is made rather heavier, and is provided with a wearing ring inside of staves, and also with a sleeve for the protecting cone. The steam bottom extends up into and around the cone, and at its top carries the bearing for the pan-spindle. By this arrangement a greatly increased heating surface is obtained. A rust joint is made between the cone on the steam bottom and the main-pan cone, while the steam bottom proper is bolted to the pan-bottom in the usual manner. Exhaust steam is used for heating, the steam being admitted on one side of the bottom and exhausted at the other, a valve being provided for regulating or shutting off. The pan-spindle step is carried on a bracket cast on the main driving shaft-box, and permits the removal of the shaft without disturbing spindle. The friction-ring through which the pan is driven is bolted to the gear, so that it can at any time be replaced

independently of the other parts when worn or broken. In front of the pan is a quicksilver bowl with a pan siphon for draining the pan of quicksilver and pulp when in need of repairs. These pans are 5 ft. 2 in. in diameter (inside), and weigh 8,500 lbs.

M. P. Boss's Standard Settler is a cast-iron pan, 8 ft. in diameter, with muller arms and driver cast in one piece, to which the muller-plate is bolted. The friction-gear and arrangement of spindle-step are the same as in the pans. The shoes are worked close to the bottom but do not touch it, and, on account of the angle at which they are placed, form a strong under-current which sweeps the bottom, thus saving wear and tear. Quicksilver bowls are provided the same as for pans, and to which siphon can be applied for draining. The settlers are fitted with heavy wrought-iron sides, and are connected together near their tops in a similar manner to the pans. The cone is cast with the settler-bottom, and is made very wide at its base with the shoes working close up to it, thus preventing the accumulation of settled pulp

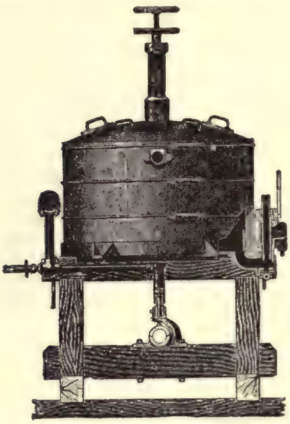

FIG. 4.

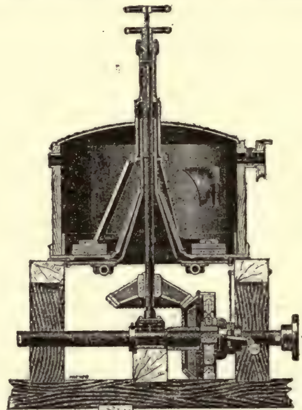

FIG. 5.

FIGS. 4, 5.—Boss's amalgamating pan.

on the bottom with the clogging and breakage that is liable to ensue. The entire surface of the bottom between the base of the cone and outer groove is swept by the shoes.

M. P. Boss's Bullion-Melting Furnace, for melting the silver bullion from the retorts, is similar to an ordinary forge, consisting of a cylindrical pan with a hemispherical bottom, lined with 2 in. of fire-clay and bone-ash mixed. The back of the furnace has a water-jacket through which pass two tuyères. At the bottom of the pan is a discharge-spout, stopped with a bone-ash plug, through which the bullion is drawn off into molds. The furnace is filled with charcoal, air is blown through the tuyères by means of a bellows, bullion fed in, melted, and drawn off into molds. It is claimed that this furnace has an advantage over the reverberatory style in melting by a reducing flame instead of an oxidizing, thus avoiding the loss of silver by oxidation.

LEACHING-VATS, ETC.—The leaching-vats used in lixiviation-mills is shown, in vertical section, in Fig. 6. In the center of the bottom is the discharge opening, 6 in. in diameter. The cast-iron discharge-tube *k* of the same inside diameter, tightly fastened to the outside of the tank-bottom, corresponds with the discharge-hole. The lower end of the tube is at right angles with the upper end, and provided with flange *o*. The valve *m*, which is provided with a rubber gasket, can be pressed tightly against flange *o* by turning the wheel *F*. The flange *o* and valve *m* are made of brass. Around the discharge opening and fastened to the bottom of the tank is the wooden polygon *v* in which is cut the groove *p*. Around the inner periphery of the tank, and high enough to give the filter bottom an inclination of at least ¾ in. to the foot, is the groove *p*. The filter bottom consists of a wooden grating made in sections, to which the filter-cloth is well fastened, and kept in position by driving tightly a rope into the grooves *p* and *p*. The air-escape pipe *d*, which reaches to the rim of the tank, enters the latter close under the filter bottom. A piece of the hose is fastened to the upper end, and can be closed by a hose-clamp. *N* is the central hose, which reaches down into the discharge-tube *k*, where it has to remain during the process of charging. This hose ought to be very stiff. Before charging the tank the discharge-pipe is filled with water through the central hose, in order to keep the latter filled with water, which will prevent the inside of the hose from being obstructed by ore. When a tank is ready to be discharged the wheel *F* is turned, and thus the valve *m* pulled back. The water is injected through the central hose, while the latter is gently moved up and down. The stream undermines the tightly packed sand and causes a continual caving-in until a funnel-shaped opening is made through its depth to the surface. Then several streams are made to play on the top, while the general hose, with checked streams, is left in position to avoid obstruction of the discharge-pipe by a too sudden rush of sand.

Mr. C. A. Stetefeldt, in a paper entitled The Details of Construction for a Modern Lixiviation Plant, read before the American Institute of Mining Engineers, June, 1891, gives the following specifications for the construction of leaching-vats: "Tanks should be made of

clear, well-seasoned lumber. In the United States Oregon pine is the best material for this purpose. The staves, from 3 to 4 in. thick, according to size of tank, should be ordered cut to sweep of radius, and from 9 to 10 in. longer than the inside depth, but not 'gained' for the bottom. The gaining of the staves, 1 in. deep, is done by hand, leaving a chine of 6 in. below the bottom. In all tanks the staves stand perpendicular to the bottoms. The bottom pieces, 3 to 4 in. thick, are cut to a diameter of 2 in. greater than that of the finished tank; they are grooved and joined by a tongue. All joints must be fitted with precision. White lead should never be put between the staves, but may be used in inserting the tongues between bottom pieces. The understructures, of substantial timbers,

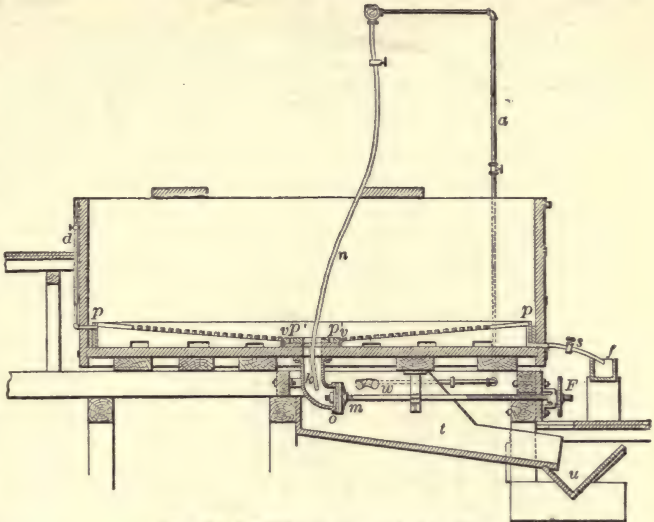

FIG. 6.—Leaching-vat—vertical section.

placed on a solid foundation, should be sufficiently high to allow access to the bottom in case of leakage. The bottoms rest on joists 3 to 4 in. wide and 10 to 12 in. deep, placed about 2 ft. 6 in. apart, so that the staves are left entirely free. Hoops are made of round iron, ¾ to 1¼ in. diameter, the threaded ends, with hexagonal nuts, passing through forged or cast iron lugs, giving preference to the former. In order to get the full strength of the rods, the threaded ends are taken ¼ in. larger than the diameter of the rod. For tanks of large diameter, each hoop is made in two or three sections; this is necessary to effect a more uniform closing of the stave-joints by tightening the nuts in two or three places. After finishing, the tanks are painted on the outside, staves and bottoms, with three coats of white lead.

"Formerly the dimensions of lixiviation-tanks were taken quite small: ore-tanks not larger than 12 ft. diameter and 3 to 4 ft. deep; precipitating-tanks, solution-sumps, and storage-tanks of corresponding dimensions. In recent works, however, ore-tanks of 16 to 20 ft. diameter and 8 to 9 ft. depth; precipitating-tanks, solution-sumps, and storage-tanks of 12 ft. diameter and 8 to 9 ft. depth are put up. As can readily be seen, the care and attention required to finish a charge in an ore-tank, or to precipitate a solution in a precipitating-tank, are independent of the size of the vessel; hence, the great advantages of large sizes.

"The capacity of an ore-tank for 24 hours depends upon the specific gravity of the ore, the quantity of first and second wash-water, and of stock-solutions required for treatment, but principally upon the rate of lixiviation. Capacity increases in proportion to diameter, but remains nearly stationary so far as depth is concerned; that is, the same number of ore-tanks will be required whether their depth is 9 ft. or only 4 or 5 ft., in order to treat a stipulated quantity of ore per day. In fact, should the rate of lixiviation increase with reduced depth, the same number of shallow tanks would put through in 24 hours more ore than deep ones. The principal advantage of increased depth consists, therefore, only in reducing the number of charges treated.

"Where water is abundant, tailings are removed by sluicing, and great depth of the charge is no disadvantage. Even where water is scarce, and tailings have to be removed by hand, deep tanks should be used. It is only necessary to provide mechanical means for moving above the tanks large buckets into which the tailings are shoveled.

"The false bottoms for the filter, and the latter itself, are prepared as follows: Wooden slats, 1¾ in. high and 1 in. wide, and separated 1 in. from each other, are fastened to the bottom. This has so far been done with iron screws bedded in white lead; I would suggest pins of hard wood. The inside of the slats, next to the bottom, is cut out in many places ¾ in. deep and 3 in. wide, so that a free passage of the solution below the filter is established. Between the ends of the slats and the staves a clear space 1½ in. wide is left. A strip of wood 1¾ in. high and 1 in. wide, previously cut with a saw in many places, and well soaked in water so that it will bend easily, is now fastened round the slats, leaving an annular space ½ in. wide between the strip and the staves. One thickness of stiff matting, covering the slats and the circular strip, but not the annular space, forms the foundation of the filter-cloth proper. The latter, No. 10 canvas-duck, is cut to a diameter 6 in. greater than the inside of the tank, so that the ends can be pressed into the annular space described above, and kept in position by forcing down a ½-in. rope."

The precipitating-vats are provided with a machine-stirrer of the construction indicated in Fig. 7, or else with a stirrer similar to a screw-propeller. The stirrer has to make about 30

revolutions per min. if the diameter of the tank is not more than 8 or 9 ft. It is set in motion or stopped by working the friction-clutch *f*. Fixed to the inner side of the vat are wings, which reach near to the bottom, are about 3 in. wide, and are kept in position near triangular pieces of board. They break the violent current around the periphery and throw the solution toward the center, thus causing a strong whirling motion. The calcium sulphide is fed into the solution in this vat, agitated by the stirrer, and the silver thus precipitated. At the bottom of the vat are suitable valves for drawing off the precipitate, which is allowed to settle, and the supernatant liquid.

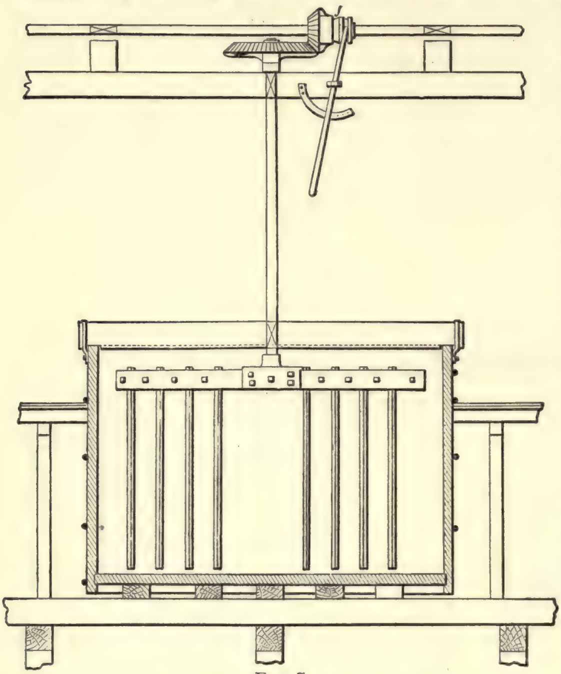

FIG. 7.

FILTER-PRESSES, ETC.—The pressure-tank used in connection with the filter-press for filtering the precipitated sulphides in the lixiviation process consists of a cylindrical tank of boiler-iron with a funnel-shaped bottom. Through the top of the tank a vertical pipe extends almost to the bottom. In the cylindrical portion of the tank is a wooden diaphragm (the vertical pipe passing through its center) which floats on the liquid within the tank. The solution containing sulphides is introduced through the vertical pipe, and rises under the floating diaphragm. A pipe at the bottom of the funnel leads to the filter-press. When the solution no longer runs freely through the latter, steam or compressed air at a pressure of 150 lbs. per sq. in. is forced into the upper part of the pressure-tank, above the floating diaphragm, and the solution is thus forced through the filter-press.

Johnson's Hydraulic Filter-Press (Fig. 8) consists of a series of round or square plates, either cast iron, bronze, or other suitable metal, having projecting lugs cast on each side for the purpose of supporting them in a press-frame in juxtaposition face to face, and are capable of being screwed up tightly between the head and follower of the press. The plates are concave on each side; the projecting outer edge or rim, being truly surfaced, maintains the plate-surfaces at distances corresponding to the depth of such rims. These rims are sometimes made separate from the plates, and varying in depth, to suit the requirements of the purchaser. The plates are covered with suitable filtering-cloth, and are also provided with ribs or channels on the plate-surface under the cloth, to allow the filtrate to flow away to the outlet formed in the bottom of the filter-plate at the back of the cloth. The spaces between the cloth-lined plates form chambers or cells, into which the liquid or semi-liquid material to be filtered is forced under pressure. A passage or opening, also lined with cloth, is formed through each plate, so that there is a free communication between the several filtering-cells. When the liquid or semi-liquid material to be filtered is forced into this battery of cloth-lined chambers or cells, the liquid is forced through the filtering-cloths

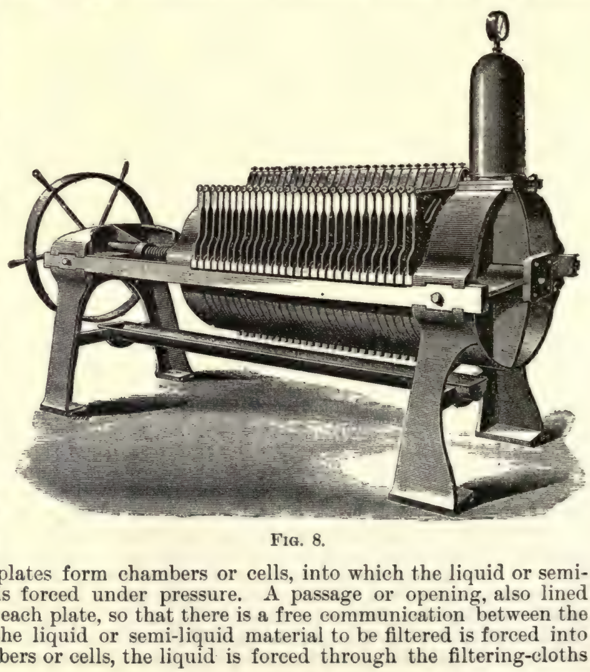

FIG. 8.

which cover the plates, and flows away to the outlet of the plate by following the channels or grooves in the plates, which have free communication with the outside of the filter. The solid matter is stopped back on the surface of the cloth, and by a continuance of the operation ultimately fills the cells. It is then removed from between the two cloth-covered concave plates, forming any one of the chambers, in a state of almost perfect dryness, by unscrewing the press and separating the plates, without removing the cloths.

The Roessler Converter is an apparatus for the condensation of sulphurous acid and its conversion into sulphuric acid, which is used in silver-refineries where *doré* bullion is parted by sulphuric acid, and in lixiviation-mills where the precipitated sulphides are refined by roasting. It consists of a cylindrical leaden tank, 8 or 9 ft. high and 5 ft. in diameter, through the top of which is introduced a 6-in. leaden pipe, extending nearly to the bottom of the tank, where it branches into two arms. These arms connect with a hollow, leaden ring, supported horizontally a few inches above the bottom of the tank, with numerous holes drilled in its lower side. The bottom of the tank is provided with a valve for discharging precipitates. The tank is filled rather more than half full with a not too acid solution of cupric sulphate. The operation of the converter is as follows: Sulphurous acid from the muffle-furnaces in which the sulphides are roasted is forced into the tank by a Körting injector through the pipe in the top, escaping through the holes in the leaden ring at the bottom. The sulphurous acid reduces the cupric sulphate in solution to cuprous sulphate, as is shown by the change in color of the solution from blue to dirty green. If, now, air is blown into the solution, the cuprous sulphate is oxidized, forming cupric sulphate again, and setting free sulphuric acid. In practice the sulphurous acid and air are forced into the tank together by the injector and the reactions go on simultaneously and indefinitely. If the liquor reaches a certain concentration in free sulphuric acid, however, the reaction is weakened; hence, either cement copper, scrap copper, or copper oxide, are put into the tank to neutralize the free acid. If the sulphuric acid from the muffles is not too much diluted with other gases, from 80 to 90 per cent of it, it is claimed, will be converted into sulphuric acid; but late investigations at the Marsac mill, Park City, Utah, have shown the worthlessness of this apparatus for acid-making, although it saves quite an amount of silver volatilized and carried over mechanically from the roasting of argentiferous precipitates.

Refining of the Sulphides.—Until recently these have been sold directly to the smelters, save in some mills where they have been reduced on a vaso or lead-bath after an oxidizing roast. Latterly, however, aided by improvements, some of the details of which have been patented by C. A. Stetefeldt, a refinery now in successful operation has been built at the Moosac mill, belonging to the Daly Mining Co., at Park City, Utah.

The operation consists in: 1. Matting the sulphides in an iron pot; 2. Roasting the pulverized matter in a muffle-furnace; 3. Dissolving the roasted matter in dilute H_2SO_4; 4. Crystallizing, $CuSO_4 + 5H_2O$, from the solution; 5. Washing the silver residue, pressing it into cakes, and melting the cakes into bars. The matting-furnace contains a cast-iron pot 3 ft. 2 in. from the top and 11 in. deep, with a bottom 2 in. thick. This is set in a fireplace and is covered by a hood of sheet-iron. A stove-pipe then connects with the Roessler converter mentioned above. The matte is pulverized in a Brueckner base pulverizer, such as is used in similar work at Mansfeld, Germany. The muffle-furnace in which the roasting is done is oval in shape, 7 ft. long and 4 ft. 6 in. wide, with a cast-iron plate serving as a bottom. The end of the muffle is connected by 4-in. gas-pipe with the Roessler converter. The dissolving tanks are lead-lined, and are 3 ft. 6 in. in diameter and 5 ft. 8 in. high. The bottoms are conical, with a discharge-hole at the end of the cone. A lead pipe allows the heating of the solution by the introduction of steam. The filter-tank below this last is also lead-lined, and is provided with an asbestos filtering-cloth covered by a perforated lead plate. The crystallizing tanks for $CuSO_4 + 5H_2O$ are of normal design. The cement copper precipitating tanks have a V-shaped bottom, and have grates on which the scrap-iron rests. The tanks are divided into four compartments each, through which the solution is circulated by a Korting ejector. At the ends of the tanks are gates through which the cement copper is discharged. A Watson & Stillman hydraulic press, with a mold 6 in. in diameter and 4 in. high, is used to compress the cement silver precipitate. Pure glycerine is used in place of water in the pump-tank. The cakes, after pressing, are dried in a small annular chamber about the chimney of the matting-furnace.

Expenses of the process, when a monthly total of 5¼ tons is treated, containing 61,950 ozs. of silver and 2,625 lbs. of copper: Labor, \$299; coal, 15 tons at \$4, \$60; acid, 4,725 lbs. at 2·4 cents, \$113.40; coke, \$15; wear and tear, \$30; express and refining charges of 65,210 ozs. bullion ·950 fine, \$912·95; total expenses, \$1,430.25. From this must be deducted the value of the bluestone, \$555.95; making a net total expense of \$874.40, or 1·4 cent per fine oz. of silver.

Works for Reference: The Metallurgy of Silver, by Manuel Eissler, 1889; *The Metallurgy of Silver, Gold, and Mercury in the United States*, by T. Egleston, vol. i, 1887; *Leaching Gold and Silver Ores*, by C. H. Aaron, 1881; *The Lixiviation of Silver Ores with Hyposulphite Solutions*, by C. A. Stetefeldt; The Lixiviation of Argentiferous Zinc-blende and Galena, by Ottokar Hofmann, *Engineering and Mining Journal*, February 9, 1888, *et seq.*; *Cupric Chloride and the Russell Extra Solution in Silver Leaching*, by C. H. Aaron, ibid., May 11, 1889; Trough Lixiviation, by Ottokar Hofmann, ibid., September 10, 1887, *et seq.*; Trough Lixiviation, by Ottokar Hofmann, *Trans. A. I. M. E.*, vol. xvi, 662.

Mine-Pump: see Pumps, Reciprocating.

Mine-Submarine: see Torpedo.

Mining-Machine: see Coal-Mining Machines and Drills, Rock.

MITERING MACHINES. Mitering seems a very simple operation, but where there is a great deal of it to do, as in picture-frame making and in cutting molding for trimming panels, it is desirable to have an appliance that shall operate with speed and give angles that are mathematically correct, and have surfaces which will make good glue joints.

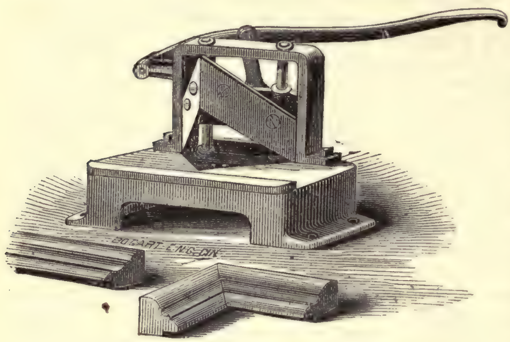

FIG. 1.—Hand mitering machine.

For cutting narrow moldings, a hand mitering machine, Fig. 1, consists of a frame in which there travels a cross piece, to which there are attached two knives at right angles to each other, and each at 45° to the plane of the cross head. The ends of the knives which are attached to the cross head are lower than either joint, so that there is a draw cut from the outside of the molding to the center. The apparatus is worked by a hand lever.

A development of this machine, for working heavier moldings, has a treadle which forces down the knives with greater power than could be got by hand.

By the use of these machines, by one motion of the crosshead the molding is cut in two and both angles of the miter are made.

MOLDING MACHINES. Under this head there are many classes, the most important of which are outside machines, which have the bed, with two or three of the heads, outside the frame of the machine ; inside machines, which have all the heads and tables inside of the frame ; edge-molding machines, which have the heads placed vertically in a table, and are designed for molding the edges of carved work ; carving and recess molding machines, which are for face molding or working forms of panels in the surface of work ; and universal wood-workers, which are combinations of the outside molding machines with a machine for planing out of wind, grooving, etc., producing straight work only.

Outside machines, which are the most common, are made with from one to four heads. Inside machines properly have four cutter heads ; edge-molding machines have either one or two spindles, the single-spindle machines being arranged to run and cut in either direction, and the double-spindle machines running in one direction.

The Egan Four-sided Molder.—In the 9-in. four-sided molder shown in Fig. 1, and brought out by the Egan Co., the table, together with the side heads and the lower head, is raised and lowered by a large hand wheel in front; the lower head has both independent vertical and lateral adjustment, as have the side heads, which can also be set beveling if desired. By this plan of having the side heads raised and lowered, raising and lowering the table does not interfere with the cut of the heads. The feed consists of four driven rolls, two above and two in the table, and all geared. The table can be dropped 16 in. The upper feed rolls are hung on trunnions, and raised and lowered parallel. The pressure on the front or back roll can be increased or diminished at the will of the operator.

The Rowley & Hermance Molder.—A 10-in. four-sided molder, shown in Fig. 2, and made by Rowley & Hermance, is one of a series of different sizes of the same class of machine, by the same makers. Its frame is heavy and cast in one piece, which makes it more rigid and steady as an inside molder. It has an outside bearing for the outer end of the top cutter-head shaft. There are two 5-in. feed rolls above, and two below. The gearing which drives the lower rolls is not affected by lowering the table to the full capacity of the machine. The feed works are started and stopped with a binder. The boxes supporting the main arbor are so arranged that the wear caused by the belt forcing the arbor toward the countershaft is confined to the bottom of the box, and can be taken out by tightening the caps. The belts which run the side heads do not pull on the caps which support them. The bottom and side heads are adjustable both horizontally and vertically.

The Frank Universal Wood-worker.—In this machine, the front and back tables are each borne upon two screw columns, and may be raised and lowered together or independently by hand wheels operating chains gearing with sprocket wheels on the screws. The fence in this machine is divided at the line of the cutter, the front part resting on the front table, and the back part resting on the back table, no matter what the height of these with respect to each other or the rest of the machine.

The Smith Blind-finishing Machine.—This is a machine for finishing blinds, cutting the rebate, and beading and joining them, manufactured by the H. B. Smith Machine Co. It has two horizontal cutter shafts, lying parallel in the same vertical plane, and the upper one borne by a carriage having a vertical adjustment on a vertical column, to suit the varying widths of sashes. The stock slides between parallel ways, one above and the other below, the upper one having the same vertical adjustment for sash width that the upper cutter has. Both the top and the under cutter-heads are so constructed and placed as to give an even draw cut on the work, and are furnished with chip breakers and shavings bonnets.

It may be said in connection with outside bearings for horizontal mandrels, such as are used on molding machines, that if the machine is properly designed and constructed they

will be entirely unnecessary, and they are certainly very inconvenient, being in the way in changing cutter-heads, while those that are furnished are seldom strong enough or rigidly enough attached to be of real service, as they should be.

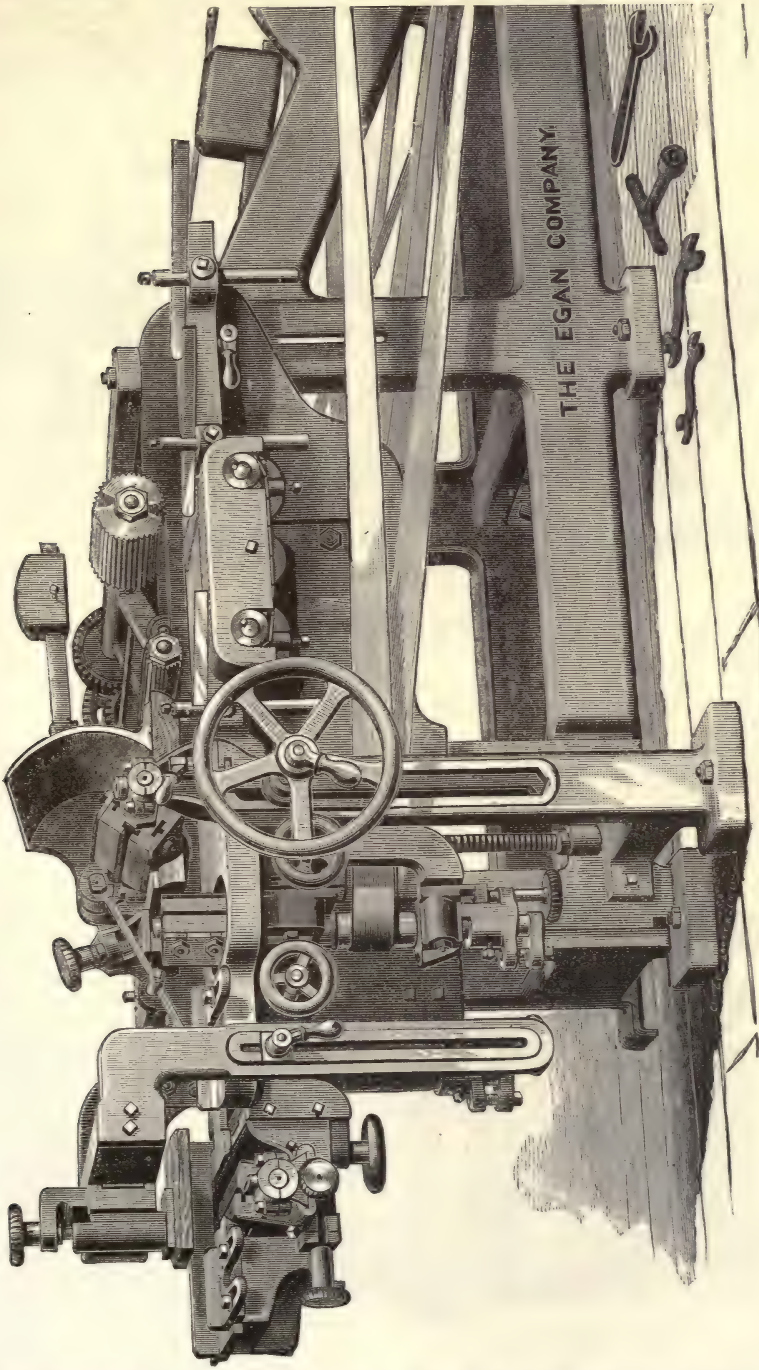

Fig. 1.—Egan four-sided molder.

Shapers and Friezers, more than most other wood-working machines, should be so well designed and constructed that they will do accurate and perfect work, all pieces that they produce being curved and molded, and their sharpness and accuracy would be lessened

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by the use of sandpapering machinery, however carefully handled. If, then, it is desired to make work that has no roughness of surface, freedom from undue jar and vibration must be obtained by giving the machine strength and solidity throughout, as well as careful workmanship and fitting. As the higher the speed the cleaner the work, it is essential that the bearings be long enough and good enough to stand high speed for a long time, under heavy pressure, without heating or wear. It is best that the mandrels of shapers should be arranged to run right or left to best suit the grain of the material, and that the change from one direction of rotation to the other should be made promptly and by the foot, in order to

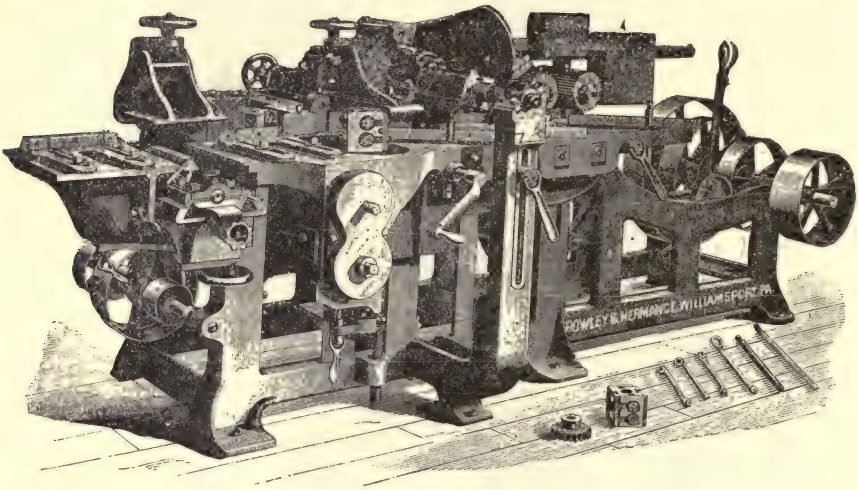


Fig. 2.—Rowley Hermance molder.

leave the operator the use of both hands. The friction devices which have come into use in so many different types of wood-working machinery come into play with great efficiency and satisfaction.

The Bentel & Margedant Shaper.—In this machine the lower part of the mandrel is shaped into a wide-faced step, resting on a gun-metal bearing plate, with special provision for adjusting itself to a full bearing, and an adjusting screw to take up wear and play. The step of the mandrel, its side and end bearing of gun metal, are at all times covered with and turning in oil, and the lower end of the journal or step is arranged with an additional large journal-bearing, with a cup held by four bolts; and the mandrel housing raises and lowers by a worm gearing, which makes impossible any accidental jarring down of the mandrel.

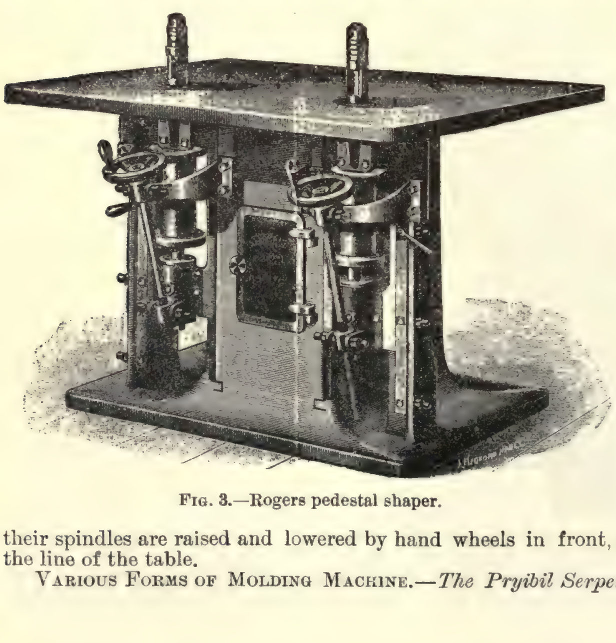


Fig. 3.—Rogers pedestal shaper.

The Rogers Pedestal Shaper, Fig. 3, made by C. B. Rogers & Co., has some very desirable features as a variety molder. There is a solid pedestal frame, having each side of it a column or post extending from the base to the table of the machine. The yoke boxes are supported by six posts and by the pedestal, so that the spindles are perfectly aligned. The yokes and their spindles are raised and lowered by hand wheels in front, and may be dropped below the line of the table.

Various Forms of Molding Machine.—*The Pryibil Serpentine Molder*, shown in Fig.

4, is adapted to a wide range of work. but is especially fitted for making such moldings as extend around the backs and ends of sofas. There is a horizontal spindle, bearing fly-cutters at each end, those on one end extending partly through a horizontal upper table bearing a proper guide or fence. The work is laid upon the top of this cutter, and guided against a gauge and collar, which determine the position and depth of the molding. Flat work is done upon adjustable tables borne on knees at the side of the machine, the cutters on the other end of the spindle from that for doing the serpentine work, working over those tables.

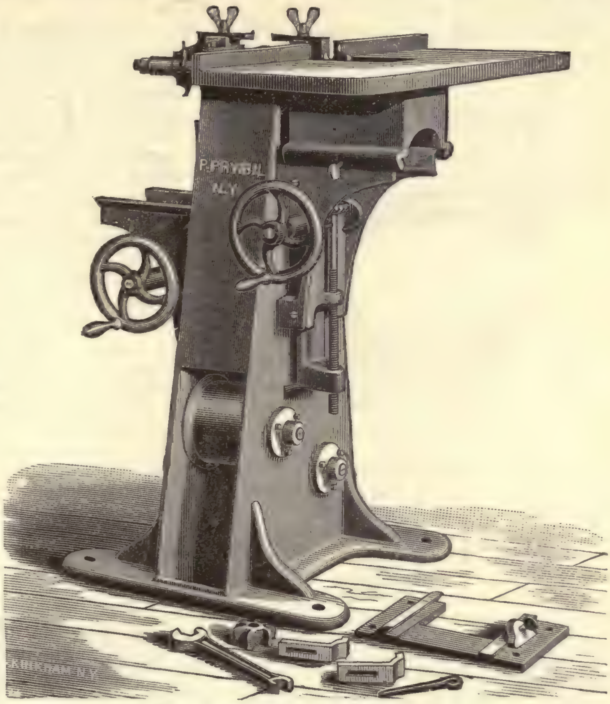


Fig. 4.—Pryibil serpentine molder.

The Variety Wood-worker.—For American use what is known as the variety wood-worker has proved a great boon, having for small establishments producing a variety of work a great range of size and variety of character of work. Such a machine is intended for planing out of wind, straight or taper surfacing, rabbeting door frames, rabbeting and facing inside blinds, jointing, beveling, gaining, ploughing, making glue joints, squaring-up bed-posts. table-legs, etc., raising square, bevel, or ogee panels, working beads and circular moldings, ripping, cross-cutting, tenoning, etc. The arbor is horizontal, and bears at one end a cutter head, and at the other is arranged for a saw or an auger ; this latter being attached to the free or overhung end. The cutters on the rotating head work through a divided horizontal table provided with a vertical fence ; the boring end has a separate table, borne by a bracket and having its own fence. While this machine has not the range or dimension nor variety of work that is characteristic of the universal wood-worker, it is a very handy class of machine for small shops, and a good time-saver and money-earner.

Shaft and Pole-cutting Machines.—The shaft and pole-rounding machine shown in Fig. 5

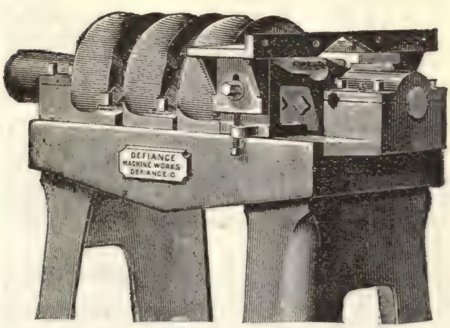


Fig. 5.—Shaft and pole rounding machine.

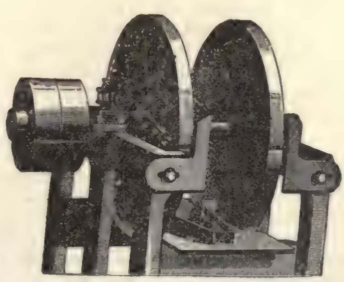


Fig. 6.—Pole heel-tapering machine.

has four cutter heads, each having three flat shear-cut knives. These heads are used for rounding, containing various widths of knives from $1\frac{1}{2}$ to 3 in., their edges ground different shapes to suit the work. Two adjustable rings or guides surround each head, and are adjusted to or from each other for regulating the depth of cut. The fourth head, which forms a buzz-planer attachment, is furnished with straight-faced knives 5 in. wide, with

adjustable tables, and a stationary fence, on each side. The machine will work round, oval, sharp, or chamfered work, dress up fellies, fit carriage-body parts, and answer various other purposes.

The shaft and pole heel-tapering machine, shown in Fig. 6, is for tapering and finishing the heels or bent ends of shafts. There are two disks, each 24 in. in diameter, and each bearing in its face three flat knives set at the proper angle to give a shear cut, the maximum length of cut being 18 in. The end of the pole or shaft to be tapered is placed on the table, between the disks, between the parallel guide and cutter head, and moved toward the spindle until a stop or end gauge is reached. By repeating this operation with the opposite head, both sides of the shaft pole are finished without turning over or reversing the work.

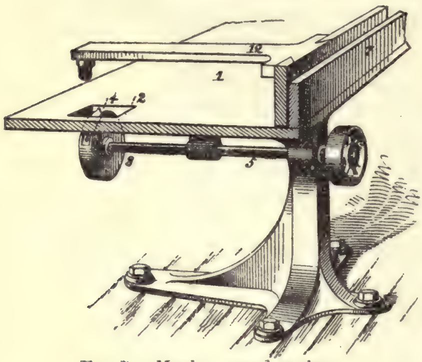


FIG. 7.—Mankey wood-worker.

Panel raising is an important operation in sash and door manufacture. There is often used a machine having two cutter-heads, one above and the other below the table, with a wide table to support the stuff, and a supplemental table or frame in front to suit the width of the panel. The cutters on these heads, both of which are vertical, are set at an angle to produce a drawing cut, and finish the surface smooth; and as they have no corners to wear away, the beds are not easily destroyed and last a long time. The under head rises and lowers with the table, and has also a vertical adjustment on the bed for accurate setting; it is belted direct from the countershaft. There are two geared sectional feed rollers and a friction roller in the table, with a spring and pressure bar to retain the stuff in place. Such a machine as this may, by removing the long hold-down spring, and putting in other heads and cutters, be turned into a machine for sticking sash, molding, etc.

MANKEY WOOD-WORK.—This name is applied to a new variety of ornamental woodwork, which is manufactured by the Mankey Decorative Co., of Williamsport, Pa. It depends upon a novel invention in woodworking which possesses a peculiar interest. It is based upon the principle that wood can be cut crosswise the grain by means of rotary cutters, provided the cutters be driven at a high speed, and the work be brought up to them under a very slow feed. By giving the cutters different configurations, channels or grooves of almost any desired cross section can be produced; and when these are combined, the most intricate geometrical patterns can be made in solid relief upon the surface of the wood. The machine on which this is done is very simple, and is represented in Fig. 7. It consists of a table, *1*, having an opening, *2*, and mounted on a suitable standard. In the standard is journaled a shaft, *5*, which carries a rotary cutter, *4*, which extends up through the slot, *6*. On the table, and against a ledge, *7*, thereon, rests the vertical bar of an arm, *12*. This arm and its bar are loose, and may be slid along on the table in contact with the ledge, *7*. The work is fastened on the under side of a guide (not shown), which receives the vertical pin, shown on the end of the bar *12*, and by means of which guide the plank to be operated upon by the cutter, *4*, can be set at any desired angle to the cutter. The workman grasps the bar, *12*, in his hand, and pushes it along, thus feeding the work to the cutter, *4*, which is usually driven at a speed from five to six thousand revolutions per minute. In Fig. 8 we give a number of examples of the kind of work which is thus done. At *1*, *2*, and *3* are shown specimens of simple cross cutting, the channels being made directly transverse

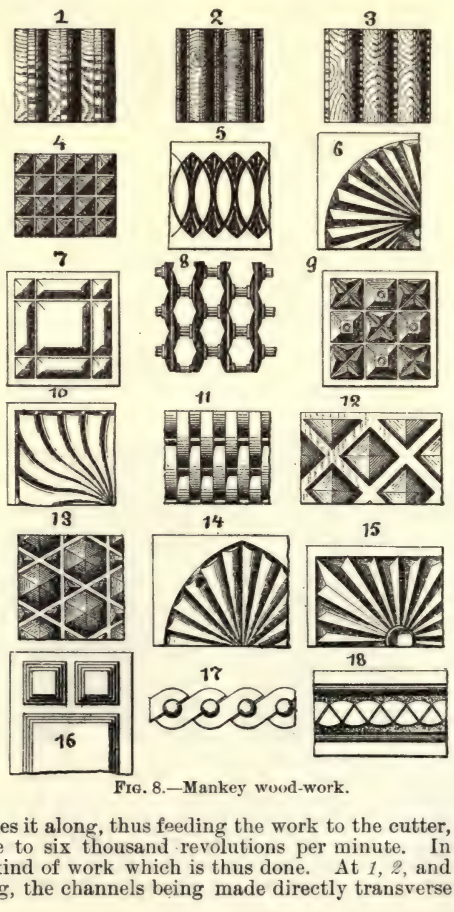


FIG. 8.—Mankey wood-work.

the grain of a board or plank. One result of this cutting is the bringing out with great clearness of the grain of the wood, which, of course, is totally obscured when the timber is cut with the grain. Nos. *4*. *7*, *12*, *13*, and *16* are examples of paneling made by intersecting grooves, producing figures in solid relief. Nos. *5* and *10* illustrate effects produced by curved grooves intersecting and combined. Nos. *6*, *14*, and *15* are patterns produced by radial grooves. No. *17* is an ornamental trim produced by cross cutting a board on two sides, as shown in No. *1*, for example, and then slitting the board longitudinally, the ornamental figure being afterwards produced by stamping, or any other convenient way, on the faces. *18* is simply a piece of ordinary molding, with a strip made exactly the same way as *17*, but ornamented differently on its face, glued thereto. No. *8* is an open-work pattern produced from a board cut as in No. *1*, then slit longitudinally, and then the several strips combined with the straight intermediate pieces, the whole glued together.

The ingenious basket-work shown in No. *11* is simply a board cut as in No. *2*, then divided into strips, and the strips glued together sidewise, so that the narrow elevation in one comes opposite the broad elevation in the other.

The number of patterns which it is possible to make in this way is almost indefinite; and the cheapness of the work is one of its principal advantages. A complete panel, such as *17*, is easily produced from the plain plank in the space of less than two minutes, and at a cost of a few cents.

MORTISING MACHINES. *The Fay Car Mortising, Recessing, and Boring Machine*, shown in Fig. 1, is for mortising by a rotating cutter, as in heavy timbers. Both the cutting and the boring tools work in a heavy spindle, which has an adjustable frame gibbed to a column

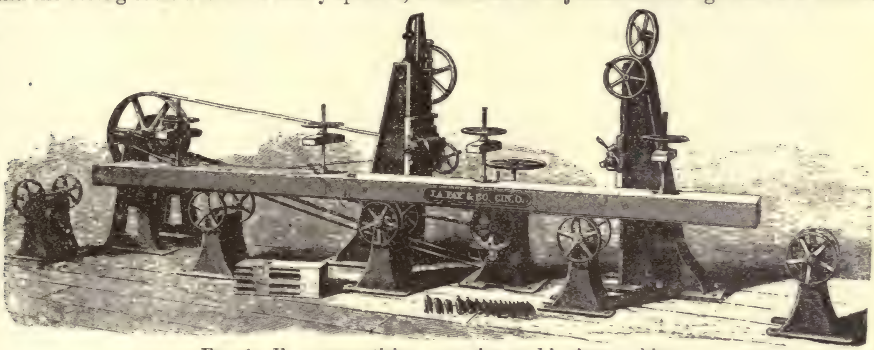


FIG. 1.—Fay car mortising, recessing, and boring machine.

for vertical movement. There is also a horizontal adjustment for governing the depth of the recesses, which are gauged by a suitable stop on the front of the frame. The weight of the frame is counterbalanced. The table bearing the timber to be mortised runs on large rollers, and has either hand or power feed, as desired; the power feed being used to feed from one mortise to the other, and the hand feed to work from one end of the mortise to the other. The table is made in sections, and may be of any length desired; the roller stands, being independent, may be set at any distance apart wished. The machine may have an auxiliary boring machine at one side towards one end. This machine works with a cutter which first bores its way into the side of the piece being mortised, and then, by cutting on its side, extends the hole to any desired length; making mortises having semi-circular ends. They will, of course, work to any desired depth, making either a blind or a through mortise, as desired.

The Egan Automatic Square-chisel Car Mortiser and Tenoner, Fig. 2, will not only cut heavy mortises, but make end tenons, gain, or mortise clear through a timber 9 in. thick, and countersink for bolt heads. The frame consists of a casting cored out at the center, and bearing at one end a knee in which the square chisel bar plays, and on its top, at the opposite end from the knee just mentioned, a table having an upright bracket, against which the side of the timber to be mortised bears. A clamp piece on this bracket holds the timber down. There is a dead roll in the table, for facilitating feeding the timber endwise across the machine. By a hand wheel the mortising bar is raised or lowered to suit any point on the width of the timber; by a screw and hand wheel, the mortising bar is brought up to the timber and the square chisel forced through; a hand lever performing for the auger

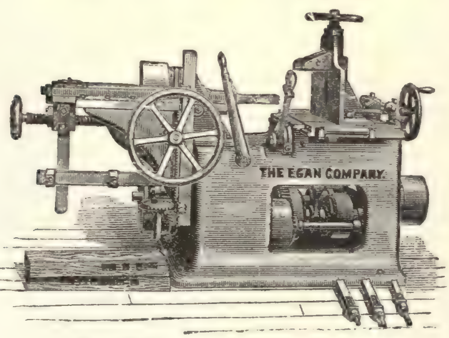


FIG. 2.—Car mortiser and tenoner.

the same function. The cross movement of the bed is controlled by a friction clutch having steps to gauge the length of the mortise. The chisel mandrel is driven by a friction gearing with a quick return ; and there are suitable stops for gauging the travel of the slide ; also a regulating screw for changing the position of the chisel to suit the work. An extra boring attachment is fitted to the machine for boring joint bolt holes, side and general work.

The Egan Hub Mortiser and Borer, shown in Fig. 3, has a single chisel bar with vertical stroke, the amount of which may be varied by altering the angle at which the short connecting rod from the crank disk meets that from the upper end of the boring bar. The change in the stroke is accomplished by a treadle, and it is claimed for it that it prevents the slightest jar upon the foot even when mortising without first boring the hole to admit the chisel. The mortising chisel is reversible on the Jack-in-the-box plan, so as to cut either end of the mortise square. The boring mandrel has vertical traverse and is counterweighted ; it is driven by beveled gearing from a horizontal axis belted at the back. The reverse may be controlled by the operator at will, or it will work automatically if set to do so. The boring bit is in line with the chisel, and there is a stop for gauging the depth of boring. The chuck for holding the hub is spaced to mortise for 10, 12, 14, 16, or 18 spokes, whether in line or staggering. One end of the hub is held by two jaws, parted by a right and left-hand screw. The other end of the hub rests in a cup of suitable size. The table has a lateral movement across the machine, parallel with the hub axis, the cross feed being given by a hand wheel.

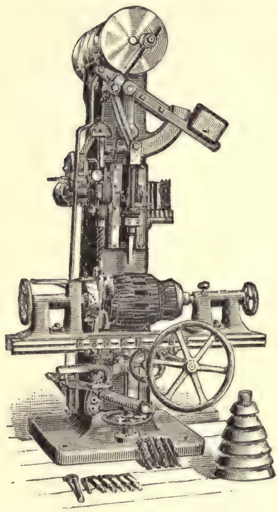


FIG. 3.—Hub mortiser and borer.

An automatic double-chisel hub-mortising machine, constructed for mortising or re-mortising hubs from 6 to 16½ in. in diameter, and cutting mortises in hard wood up to 2½ in. wide and 5½ in. long, either straight or staggered. In operation, the table carrying the hub is lifted to the chisels until the full depth of cut is reached, and remains stationary until the mortise is complete, when it descends, the hub turning one notch of an index plate, ready for the next mortise. The gigging, spacing, feeding, etc., are automatic. The capacity is 75 to 80 hubs per hour. The operator starts either the boring or the mortising bar, as desired, by a friction gear and treadle. In relieving the friction an automatic brake is applied, stopping the machine at once.

Mortising Tools.—Some mortising machines for sash work have the disadvantage of not cutting for the ends of the pulley flanges, and of not cutting and rebating long enough for them to allow the screw to enter the wood without splitting.

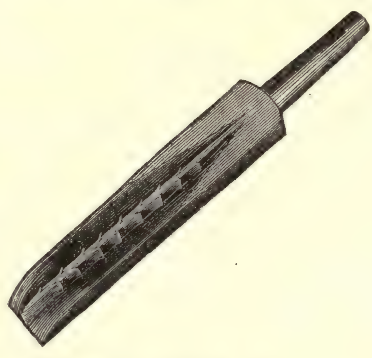


FIG. 4.—Mortising chisel.

A mortising chisel, Fig. 4, which is especially adapted for drawing from the work the chips that it produces, has extending down its back, upon the side which bears the bevel, a thin rib at right angles to the blade of the chisel ; and from this rib there project a number of small barbed lips which serve to draw the chips from the hole.

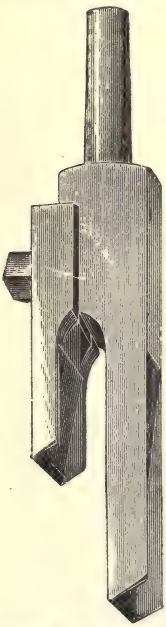


FIG. 5.—Mortising chisel.

A chisel for mortising in sash pulleys, shown in Fig. 5, consists of two chisels, each of which has a cutting edge of L section, and both of which operate at once, one of them cutting in advance of the other about half the stroke of the chisel bar ; their cutting edges being placed so as to face in the same direction. The longer of the two chisels of course cuts first, mortising clear through the pulley stile, and the short one, which is wider than the other, mortises for the flange of the pulley at the same time, thus finishing the pulley in one handling.

MOTORS, ELECTRIC. The term "electric motor" includes all apparatus by which electric energy is converted into mechanical energy. This can be accomplished (1) by the attraction that an electro-magnet exerts upon an iron or steel armature ; (2) the mutual

attraction between two electro-magnets ; (3) by analogous principles based upon the attractive force exhibited between masses of magnetic metal, and (4) the action of a magnet upon a field of force created by the passage of currents in neighboring conductors. To these must be added that small experimental class which depend for their action on the attraction and repulsion of statically charged surfaces.

HISTORICAL.—The discovery by Oersted, that the magnetic needle could be deflected by the passage of a current in proximity to it, was closely followed by that of Arago and Davy, who showed, independently of each other, that iron and steel could be magnetized by the passage of a current through a wire wound around them. Sturgeon utilized this in the construction of the first powerful horseshoe magnets. These principles were soon applied to the construction of elementary electric motors, among them that of Barlow, known as Barlow's wheel, 1826. This consisted of a disk of copper between the poles of a magnet. The current was sent perpendicularly through the disk from axis to circumference, where it passed into a cup of mercury.

Prof. Joseph Henry may be said to have constructed the first electric motor acting upon the attraction and repulsion of electro-magnets (1831). It consisted of an oscillating electro-magnet provided with a simple attachment for breaking and reversing the battery current, and thus reversing the polarity of the electro-magnet, which was alternately attracted and repelled by the poles of a permanent magnet.

A large number of inventors had also constructed experimental motors, among them, Abbé Salvatore dal Negro, Dr. Shulthess, Davenport, Elias, Froment, Du Moncel, Wheatstone, Gaiffe, Hjörth, Roux, Larmenjeat, Bourbouze, Moses G. Farmer, and Thomas Hall.

Probably the most interesting of the early motors was that of Jacobi, which drove a boat on the Neva, at St. Petersburg, in 1838. This motor consisted of two sets of electro-magnets. One set was fastened to a square frame, disposed in a circle, and with the poles projecting parallel with the axis. The other set was similarly fastened to a disk attached to the shaft, and revolving with it. Each set comprised four magnets, and there were consequently eight magnetic poles. The current from a powerful battery passed through the commutator to the coils of the electro-magnets, and as the magnets attracted each other, the disk rotated. By means of the commutator on the shaft, the current was reversed eight times during each revolution, just as the poles of two sets of magnets arrived opposite each other. Attraction ceasing, repulsion took place, and the motion was thus accelerated. As the poles were alternately of different polarity, the reversals had the effect of causing attraction between each pole of one set, and the next pole of the other. In his historic experiments of 1838, Jacobi used a modified form of this motor, so as to obtain greater power.

The most celebrated early motor, next to that of Jacobi, was undoubtedly that of Prof. C. G. Page, of the Smithsonian Institution. This depended upon a different principle from that of the others. When the end of a bar of iron was held near a hollow electro-magnetic coil or solenoid, the iron bar was attracted into the coil by a kind of a sucking action, until the bar had passed half way through the coil, after which no further motion took place. Professor Page constructed an electric engine on this principle about 1850. The solenoid was placed vertically, like the cylinder of an upright engine. A rod of iron, by way of armature, was fastened to a piston rod connected to the crank of a shaft carrying a fly-wheel. The core moved downward by its weight, until its upper end was just leaving the solenoid, and thus one movement of the piston was accomplished. On passing the current, the core or piston was attracted upward, and thus the second movement was completed. A commutating device was attached to the shaft which automatically admitted the current into the coil and cut it off at the right moment. Professor Page soon improved on this single-acting electric engine by adding another solenoid, which could pull the piston in the other direction without the assistance of gravity.

A large motor of this description was constructed by Professor Page, in 1850, which developed over 10 horse-power. Professor Page sought to apply his motor to locomotion, and he actually constructed an electric locomotive to demonstrate the practicability of his scheme.

The most important of the early motors from a scientific standpoint, however, was the motor built, in 1861, by Professor Pacinotti, of the University of Pisa, and exhibited at Vienna in 1873, and in Paris in 1881. This motor, described in the *Nuovo Cimento* for 1864, had an armature consisting of a toothed iron ring, and was wound and connected practically in the same manner as the Gramme armature. As to reversibility, he remarked with keen foresight : "This model further shows how the electro-magnetic machine is the complement of the magneto-electric machine, for in the first, the current obtained from any source of electricity, circulating in the bobbins, produces movement of the wheel with its consequent mechanical work; whilst in the second, mechanical work is employed to turn the wheel, and obtain, by the action of the permanent magnet, a current which may be transmitted by conductors to any required point."

Although the reversibility of the electric motor and the magneto-electric generator had already been noticed, it was not until 1873, after the substitution of electro-magnets for permanent ones in electric generators, that the reversibility of the dynamo was fully realized, and pointed out by M. Fontaine, in the action of the Gramme machines exhibited at the Vienna exhibition of that year. Modern practice dates from this period.

GENERAL THEORY.—Dynamo machine and electric motor are convertible terms. Any dynamo can be used practically as a motor, and in most cases any motor can be used to generate a current. On purely theoretical grounds this should be possible in all cases, but in

practice it is found that the speed which is required to make some small motors act as self-exciting dynamos is so high as to render that application mechanically impossible. The reason for this is, according to Kapp, that in small motors the polar surfaces are of very limited extent, and consequently the magnetic resistance of the path traversed by the lines of force is excessively high, requiring more electrical energy to excite the field magnets than the armature is capable of developing at a moderate and practical speed.

Dynamos wound and connected for working as generators of continuous currents may be used in all cases as motors, but with some difference. A series dynamo set to generate currents, when run right-handedly (and therefore having a forward right-handed lead), will, when supplied with a current from an external source, run as a motor, but runs left-handedly, against its brushes. To set it right for motor purposes requires either that the connections of the armature should be reversed, or that those of the field magnet should be reversed (in either of which cases it will run right-handedly), or else the brushes must be reversed and given a lead in the other direction (in which case it will run left-handedly). A shunt dynamo, set ready to work as a generator, will, when supplied with current, run as a motor in the same direction as it ran as a generator; for if the current in the armature part is in the same direction as before, that in the shunt is reversed, and *vice versa*. A compound-wound dynamo, set right to run as a generator, will run as a motor in the reverse sense, *against* its brushes, if the series part be more powerful than the shunt, and *with* its brushes if the shunt part be the more powerful. If the connections are such (as in the compound dynamos) that the field magnet receives the sum of the effects of the shunt and series windings when used as a generator, then it will receive the difference between them when used as a motor.

In several respects it is even more important that the rules laid down for the good design of generators (see DYNAMO ELECTRIC MACHINES) should be observed for motors. Eddy currents must be even more carefully eliminated. According to Mordey, in a generator the self-induction in the sections of the armature coil, and the eddy currents in the core, are antagonistic; in the motor they tend to increase one another. Also, the greatest attention must be paid to proper mechanical arrangements for transmitting to the shaft the forces that are thrown by the magnetic field upon the conducting wires around.

GOVERNING OF MOTORS.—One of the earliest attempts to secure an automatic regulation of the speed was that of M. Marcel Deprez, who in 1878 applied an ingenious method of interrupting the current at a perfectly regular rate by introducing a vibrating brake into the circuit. It ran at a perfectly uniform speed, quite irrespective of the work it was doing. Deprez also showed that the torque of a motor depends only on the strength of the field and on the current, but does not depend on the speed. In dealing with this matter, in *La Lumière Electrique* of October 3, 1885, he says: "If a current traverses a motor having an armature of the Pacinotti type, the turning effort of the latter is independent of its state of movement or rest, and in motion it is independent of the speed, provided the strength of the current is maintained constant. Inversely, if the static moment tending to resist the motion of the armature is maintained constant, the current will thereby automatically be kept constant, whatever means we may employ to vary it. Since with a constant load the energy given out is proportional to the speed, and since the electrical energy supplied to the motor is the product of current and electro-motive force, it follows that if the current is constant the speed must be proportional to the electro-motive force."

Automatic Governing.—It was pointed out (see DYNAMO ELECTRIC MACHINERY) that a properly designed shunt-wound dynamo, if run at constant speed, would generate a *constant E. M. F.* at all loads. Conversely, it can be shown that a shunt-wound machine, if supplied with current from mains at a constant potential, will maintain *constant* speed at all loads. For this reason the large majority of motors in use at present are of the shunt-wound type, connected to constant potential circuit, as they regulate automatically.

In the same way, motors can be governed by compound winding of the field magnets; but in such case the series coil must be wound differentially to the shunt winding to maintain constant speed. This method is claimed by Sprague and Ayrton and Perry. With this method of winding, the coil in series with the armature tends to weaken the field magnetism, at any increase in load.

Centrifugal Governing.—Professors Ayrton and Perry have also proposed several forms of "periodic" centrifugal governor, a device by which, in every revolution, power is supplied during a portion of the revolution only, the proportion of the time in every revolution during which the power is supplied being made to vary according to the speed. The main difficulty with such governors is to prevent sparking. But there is a still more radical defect in all centrifugal governors; they all work too late. They do not perform their functions until the speed has changed.

Dynamometric Governing.—Prof. S. P. Thompson has devised another kind of governor which is not open to this objection. He proposes to employ a dynamometer on the shaft of the motor to actuate a regulating apparatus, which may consist either of a periodic regulator to shunt or interrupt the current during a portion of each revolution, or of an adjustable resistance connected in part of the circuit. The regulator in this case is therefore worked, not according to the speed of the motor, but according to the load it is carrying. Any change in the load will instantly act on the dynamometric governor before the speed has time to change.

Other Methods of Governing.—Sprague and André have designed motors in which the field magnets are wound in two separate circuits, one with thick and the other with thin wire, the current dividing between them, and the armature connected as a bridge across

these circuits, exactly as the galvanometer is connected across the circuits of a Wheatstone's bridge. Another method of governing, employed by Brush and Hochhausen, consists in building up the field-magnet coils in sections, and by varying the number of sections in circuit, or the mode of their connection, obtaining regulation of speed. This method is usually employed only on constant-current motors.

The method of constructing a motor with coils in sections, so that a movable internal core may be successively attracted as successive sections are switched in, has been made use of by Deprez in constructing an electric hammer. This principle of construction was employed by Page in his motors many years previously. For a complete discussion of the various methods of motor regulation, the reader is referred to a paper by Prof. F. B. Crocker, Trans. Am. Inst. Elect. Engrs., p. 237, vol. vi., 1889.

Efficiency and Power.—It can be shown, mathematically, that the efficiency with which a perfect motor utilizes the electric energy of the current, depends upon the ratio between the counter electro-motive force developed in the armature of the motor, and the electro-motive force of the current which is supplied by the battery or dynamo. We can therefore calculate the efficiency at which the motor is working, by observing the ratio between the fall in the strength of the current and the original strength. Or, to put it another way, with two series dynamos, the electrical efficiency of transmission, when there is no leakage, is the ratio of the electro-motive forces developed in the armatures of the two machines.

Jacobi's Law concerning the maximum power of an electric motor supplied with currents from a source of given electro-motive force, is the following : The mechanical work given out by a motor is a maximum when the motor is geared to run at such a speed that the current is reduced to half the strength that it would have if the motor was stopped. This, of course, implies that the counter electro-motive force of the motor is equal to half the electro-motive force furnished by the battery or generator. Now, under these circumstances, only half the energy furnished by the external source is utilized, the other half being wasted in heating the circuit. Dr. Siemens proved, in fact, that if the motor be arranged so as to do its work at *less than the maximum rate,* by being geared so as to do much less work per revolution, but yet so as to run at a higher speed, it will be more efficient ; that is to say, though it does less work, there will also be still less electric energy expended, and the ratio of the useful work done to the energy expended will be nearer unity than before. Hence, to get maximum work per second out of an electric motor, the motor must run at such a speed as to bring down the current to half the value which it would have if the motor were at rest. That is to say, the efficiency is but 50 per cent. when the motor does its work *at the maximum rate.*

When a dynamo is used as a motor, the power is supplied to it electrically in the form of electric currents delivered at a certain potential or pressure. If C_M is the number of amperes of current which flow through the motor, and E_M be the number of volts of potential as measured at the terminals of the motor, then the electric power, in watts, P_W, given by the mains to the motor, will be found by multiplying together the amperes and the volts, or $P_W = E_M C_M$ (watts). This may be expressed as electric horse-power by dividing by 746, since 746 watts equal one electric horse-power.

$$E.\ H.\ P. = \frac{(E_M C_M)}{746}.$$

All of this power electrically supplied is not, however, turned into mechanical power, some being inevitably used up in heating the conductors (because they have electric resistance) and in magnetic friction. That part of the power which is actually utilized in turning the armature may be expressed in two ways, either electrically or mechanically.

If C_a is the amperes that flow through the armature, and E_a the E. M. F. actually generated by the rotation of the armature as it goes round in its magnetic field, then the number of watts utilized is—

$$P_w = E_a C_a.$$

The efficiency (electrical) of the motor is given by the ratio of P_w to P_W, or $\frac{P_w}{P_W}$. The power thus utilized in the armature, if expressed in electrical horse-power, will be $E_a C_a \div 746$. To express in mechanical units the power utilized by the armature, it must be remembered that the power is also the product of two factors, the speed and the turning moment, or torque.

If n stand for the number of revolutions per minute ; and F_{pf} stand for torque, or force in pound-feet—*i.e.*, so many pounds' weight acting at a radius of one foot—then the number of foot-pounds per minute is given by 2π times the product of n and F_{pf}; or,

$$H.\ P. = \frac{2\pi n F_{pf}}{33{,}000}.$$

Equating this to the electrical expression for the power given to the armature, we get—

$$n F_{pf} = \frac{33{,}000}{2\pi \times 746} \times E_a C_a = E_a\ C_a \times 7{\cdot}04.$$

Now E_a, the E. M. F. generated by the rotating armature, tends to send a current in the opposite direction through the circuit ; it is therefore sometimes called the *counter* E. M. F. of the motor. The faster the motor runs, and the stronger the magnetic field of the machine, the greater does E_a become, and the more does it oppose the flow of current through the motor.

The actual efficiencies of motors vary considerably with the power of the machine, its

method of governing, and the nature of the circuit to which it is connected. This is well shown in the accompanying tables, due to Dr. S. S. Wheeler and Prof. F. B. Crocker, which give respectively the efficiencies of machines (shunt wound) connected to constant-potential circuits, and machines (usually series wound) connected to constant-current or arc-light circuits, and the currents required at the various potentials.

Amperes required to give Different Powers on the Various Constant-potential Circuits, allowing for the Ordinary Efficiency of each Size of Motor.

Horse-power of motor.	Efficiency of motor.	Electrical horse-power required.	8 volts battery.	50 volts.	75 volts.	100 volts.	110 volts.	120 volts	220 volts.	240 volts	440 volts.	500 volts.
1/16	40%	·16	14	2·3	1·6	1·2	1·1	1·	·53	·48	·26	·23
1/8	55	·23	21	3·4	2·2	1·7	1·5	1·4	·76	·69	·38	·34
1/6	60	·28	26	4·1	2·8	2·1	1·9	1·7	·95	·87	·48	·41
1/4	62	·40	38	6·0	4·0	3·0	2·7	2·5	1·4	1·3	·68	·60
1/2	66	·76	71	11·3	7·5	5·7	5·1	4·7	2·6	2·4	1·3	1·13
1	72	1·4	130	20·7	13·8	10·4	9·4	8·6	4·7	4·3	2·4	2·07
2	75	2·7		39·8	26·6	19·9	18·1	16·5	9·1	8·3	4·5	3·98
3	78	3·8		57·3	38·2	28·6	26·	23·8	13·0	11·9	6·5	5·73
4	79	5·0		75·5	50·3	37·7	34·3	31·4	17·2	15·8	8·6	7·55
5	80	6·2		93·3	62·2	46·6	42·4	38·8	21·2	19·4	10·6	9·33
7½	82	9·1		136·	90·9	68·2	62·	56·8	31·0	28·4	15·5	13·6
10	84	12·		178·	118·	88·8	80·7	74·	40·4	37·	20·2	17·8
15	85	17·6		263·	176·	132·	120·	110·	60·	55·	30·	26·3
20	86	23·		347·	231·	173·	158·	145·	79·	72·	39·9	34·7
25	88	28·		424·	283·	212·	193·	177·	96·	88·	48·2	42·4
30	88	34·		509·	339·	254·	231·	212·	116·	106·3	57·8	50·7
35	89	40·		587·	391·	293·	266·	244·	133·	122·	67·4	59·
40	89	45·		671·	447·	335·	305·	280·	153·	140·	77·	67·
50	90	55·		829·	553·	414·	377·	346·	188·	172·	94·	83·
75	90	83·		1,243·	828·	621·	565·	518·	283·	259·	141·	124·

Volts required to give Different Powers on Various Arc Circuits, allowing for the Ordinary Efficiency of each Size of Motor.

Horse-power of motor.	Efficiency of motor.	Electrical horse-power required.	3 amperes.	6½ amperes.	10 amperes.	18 amperes.
1/16	35%	·18	44·	20·	13·	7·
1/8	50	·25	62·	29·	19·	10·3
1/4	55	·45	112·	51·	34·	18·7
1/2	62	·81	201·	93·	60·	33·5
1	68	1·47	366·	169·	110·	60·9
2	72	2·8	696·	319·	207·	115·
3	76	4·0	981·	453·	294·	163·
4	77	5·2	1,291·	596·	387·	215·
5	78	6·4	1,594·	736·	478·	265·
7½	79	9·5	2,360·	1,089·	708·	393·
10	80	12·5	3,108·	1,435·	933·	518·
15	82	18·3	4,548·	2,099·	1,364·	758·
20	83	24·1	5,991·	2,765·	1,797·	999·
25	84	29·8	7,400·	3,416·	2,220·	1,233·
40	85	47·1	11,700·	5,400·	3,510·	1,950·

An examination of the tables shows that the efficiencies range from 35 to 90 per cent., which compared with the steam engine, shows considerable superiority. The consumption of coal in steam engines of various sizes and types, varies from 2 to 10 lbs. per horse-power hour, a variation of 1 to 5 against 1 to 2 with electric motors. Further consideration shows that the amount of energy required to produce a given amount of power is not affected by the size of the motor, within moderate limits ; the gain in efficiency, if an unnecessarily large motor is used, being about offset by the losses due to its not being fully loaded. For instance, if one horse-power is obtained from a two-horse-power motor, the motor itself, being larger, will be of slightly greater efficiency ; but not being run at its best load, the result will be only about the same as if a one-horse-power machine were used. In other words, for any given amount of power consumed, the amount of energy required, and, therefore, the cost of running, is practically constant and independent of the size of the motor used, within the ordinary limits of selection. This, however, refers merely to the cost of current, and is not to be understood as lessening the imperative importance, for mechanical reasons, of choosing a motor with a considerable margin of capacity.

Various Types of Electric Motors.—The Philadelphia Electrical Exhibition of 1884 was marked by a revival of interest in electric motors, and many of the new types produced were of great merit, though the rapid advances in this field may have relegated some to obscurity. Fig. 1 is a perspective view of a motor designed by Mr. A. Reckenzaun, in 1884, and exhibited at that exhibition. The magnets are, in appearance, somewhat similar to those employed in the Siemens dynamo, except that, as will be seen from the cut, the cores are in an inclined position, the upper and lower core ends meeting at a rather acute angle. This arrangement saves space, reduces the weight, and renders the frame rigid. The armature consists of a ring, made up of a series of rings, each of which is again composed of a number of links provided with holes at their ends to receive the bolts which hold the links as well as the rings together. The links, overlapping one another, are insulated from each other in order to avoid Foucault currents.

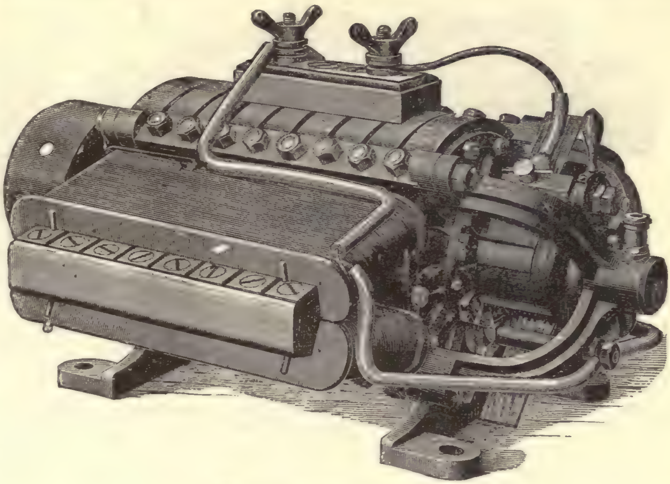


FIG. 1.—Reckenzaun motor.

From 12 to 36 bobbins surround the ring thus formed, and connect with a commutator made up of a corresponding number of sections. A pair of brush holders carry two brushes, movable within a certain range to adjust the speed of the motor. Inside the armature is a magnet, resting loosely on the shaft by means of rollers. This internal magnet is, in cross-section, H-shaped, having two pole pieces, between which a quantity of fine wire is wound lengthwise, the ends of which are connected to copper brushes, which, in running, rub against two brass collars fitted upon the shaft inside the armature. These inside collars are in metallic connection with a pair of similar collars at the commutator, where another pair of brushes rests on them, picking up a small current for the internal magnet. This internal circuit forms a shunt to the main circuit. The internal magnet, on being excited, offers two poles, each facing a like-named external field-magnet pole. Hence the passing armature bobbins are exposed to strongly magnetized pole pieces inside as well as outside, thereby utilizing also the inner parts of the wire bobbins. The internal magnet is made for larger sized motors, and may be taken out and the motor run without it. On top of the machine are two binding posts, mounted on a block of wood, to which the mains are connected. All the iron in this motor is best soft wrought-iron, no cast-iron being employed. All parts are carefully proportioned for light weight, high efficiency, and strength. In case the armature should require repairing, the bobbins need not be unwound, as in some other machines, but any one may be slipped off its section after taking out the nearest bolt, thus saving time, labor, and material.

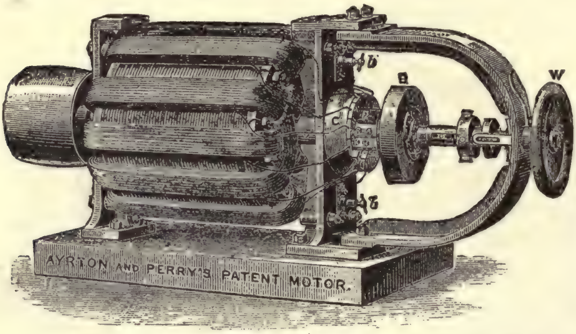
The motor exhibited in Philadelphia was of $1\frac{1}{4}$ actual horse power, and weighed 106 lbs. Its bulk was likewise exceedingly small. The motor measured in height $9\frac{1}{2}$ in., width $16\frac{1}{2}$ in., and length of shaft $20\frac{1}{2}$ in.

Professors Ayrton and Perry, of England, have devoted much attention to the study of electric motors, and have promulgated the theory that, whereas in the dynamo the field should be of great magnetic strength and the armature a weak one magnetically, the reverse should be observed in the motor—*i.e.*, the field should be a weak magnet and the armature a powerful magnet. This theory, however, has not been sustained by practical experience. They embodied their ideas some time ago in a form of motor which differs from those of ordinary construction in that the armature is kept stationary while the field magnet revolves within it.

Fig. 2 shows the Ayrton and Perry motor in perspective ; Fig. 3 shows the construction of the motor more in detail. The stationary armature, as will be seen, consists of a laminated cylinder built up of toothed rings of sheet-iron, and resembles very much the Pacinotti toothed-ring armature. The wires are wound on in sections, joined in series, and at each joint are connected to a segment of the stationary commutator, *C C*. The spindle of the revolving field magnet carries the brushes, which revolve with it.

In explanation of the operation of the motor, Professor Ayrton says that wherever the brushes, *B*, happen to be at any particular moment, there two opposite magnetic poles, at *N* and *S*, are produced on the armature, as shown in Fig. 3. As the brushes revolve, so do these poles, and the brushes, which are carried by the field magnets, are so set that the

magnetic poles in the armature are always a little in front of those in the field magnet. The latter, therefore, are, as it were, perpetually running after the former, but never catching them. From the peculiar construction of the Ayrton and Perry motor, it may be operated without any wire at all upon the revolving field magnets. This arises from the fact that the magnetism in the stationary armature induces opposite magnetism in the iron of



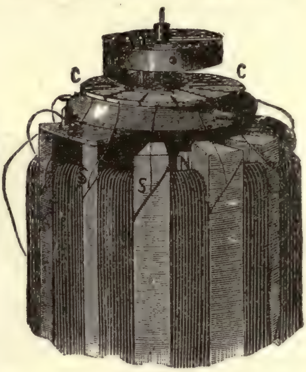


FIG. 2. Ayrton and Perry motor. FIG. 3.

the field magnets, and, as pointed out before, the brushes are so placed that the magnetic poles in the armature are always just in front of those in the iron, which latter are always running round after those in the former, but never catch up with them.

The Griscom motor is remarkable for the small space it occupies, due to its neat and compact design, shown in Fig. 4. The armature is entirely encased by the cylindrical electro-magnet within which it revolves, and by the metallic caps or disks fitted to this cylinder at each end. The cylindrical field magnet is composed of a cylinder of soft iron wired in two large coils, each of which covers nearly one-half of the cylinder, the space left between the two coils at opposite sides of the cylinder constituting the magnetic poles of this cylindrical electro-magnet. The current which passes through the wire on this magnet circulates in opposite directions in each coil or section, so that both coils combine to produce a north pole in one of the open spaces, and a south pole at the other. The result is practically the same as if two U electro-magnets were brought together with like poles in opposition, these forming a circular magnet with two consequent or combined poles, one at each junction. The iron of the cylindrical magnet projects laterally at each pole, and to these projections an ornamental brass disk is screwed firmly at one end, as shown in the figure. The binding post shown at the top is prolonged on the other side of the metallic cap, and carries one of the brass springs or brushes which serve to convey the current to the armature by pressing on the commutator. The other brush, touching on the opposite side of the commutator, is held in place by a special screw device attached to the metallic cap. The armature and the field magnet are connected in series. The current, entering the armature by the upper commutator spring, leaves it by the lower, from which it passes to the field magnet, whence it goes to the second binding post.

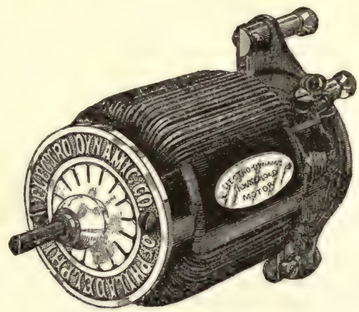


FIG. 4.—Griscom motor.

To this department of electricity, as well as to the use of motors on railways and street-car lines, Mr. Leo Daft has paid considerable attention. Fig. 5 shows a Daft motor of the early form. The field magnets are made after what is called the Siemens plan—that is, they lie horizontally, have consequent poles, one above, and the other below, the armature. They are series wound, but the coils of the field magnets are divided, so that there are two or more circuits around the core. By suitable devices these are so related that they can be thrown into series or into multiple arc, or into other combinations when there are more than two circuits, for the purpose of changing the strength of the magnetic field, to suit the electromotive force and strength of current supplied to the motors. The armatures are modeled in principle after the Gramme, but their construction is much improved, especially in respect to the manner of mounting them on their shafts.

The latest form of Daft motor is shown in Fig. 6. It will be seen that the field magnets are of the simple horseshoe form, and that the armature is of the Gramme type, as in Mr. Daft's previous models. The machine is designed to deliver normally 6 horse-power, but upon test it has been driven to as high as 11 horse-power without injurious effect.

At the Singer Manufacturing Co.'s exhibit in the International Electrical Exhibition at Philadelphia in 1884 were seen several sewing machines run by various electric motors

invented by Mr. Philip Diehl, the inventor engaged by the sewing machine company. A later design is shown in Fig. 7, in which it will be seen that the field magnets are placed vertically and hinged at the top, being supported by two side rods, cast solid with the base. The lower ends of the field magnets encircle the armature, which is also carried by journal bearings in the side rods. The method of regulation of the motor consists in separating the pole pieces from the armature. This is accomplished by means of two connecting rods fixed

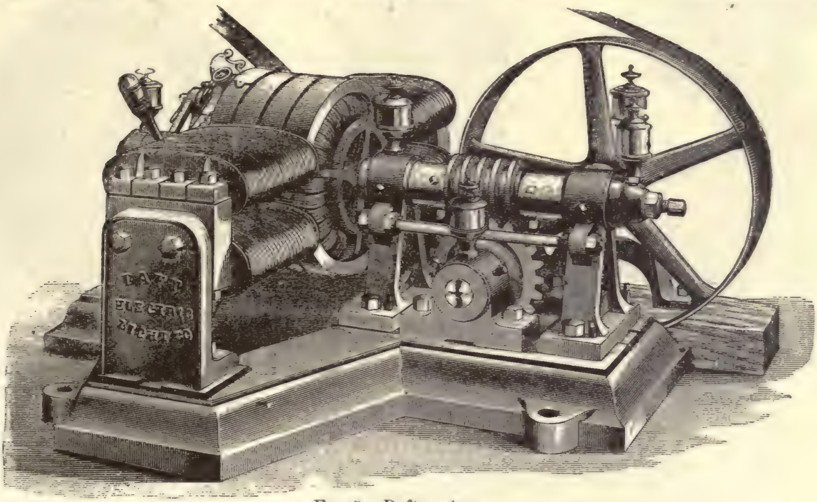


FIG. 5.—Daft motor.

to the lower ends of the magnets, and joined together by a pin which slides in a slot on the upright. A rod connected to the pin serves to raise and lower the upper ends of the two connecting rods, and in doing so the field magnets are separated or brought together, as the case may be. When used in connection with a sewing machine, the motor is secured to the under side of the table in an inverted position, and the regulating lever connected to the treadle. In this position the field magnets fall apart of their own weight and the machine does not work. It is only when the treadle is pressed and the magnets are brought together that motion is obtained. It is evident that by varying the distance between the armature and the magnets any desired speed can be obtained for fast or slow work. The armature shaft is

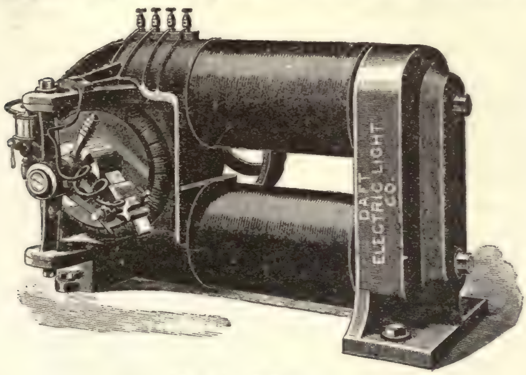


FIG. 6.—Daft motor.

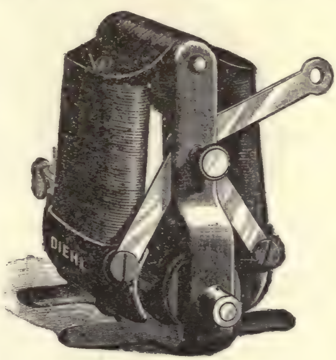


FIG. 7.—Diehl motor.

provided with a pulley, and its end is bored so that the power can be transmitted by belt or applied directly, as when driving a fan.

To avoid the necessity of belting, and at the same time do away with the presence of an auxiliary machine on the board for driving, Mr. Diehl conceived the idea of combining the motor and sewing machine into a practical unit, as shown in Fig. 8. The motor is completely housed within the fly-wheel of the machine, and connected directly with the driving shaft, so that all gearing is obviated. The details of the arrangement will be readily understood from Figs. 9 and 10, which show respectively the field magnet and armature of the motor. The magnet, which consists of a single piece, is wound with wire connected to the two terminal brushes shown. This magnet is permanently fixed to the hub through which the shaft passes. The armature, shown in perspective in Fig. 10, is of the Gramme type, and is held in position within the rim of the wheel. The wires leading from the periphery connect

to the commutator at the hub, and the brushes on the magnets bear against the segments.

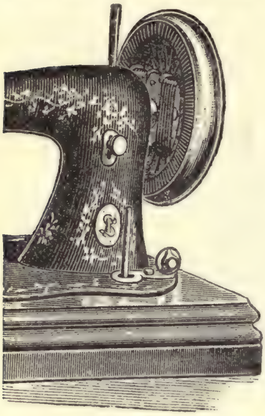


FIG. 8.

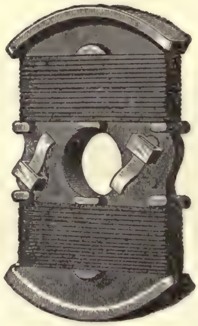


FIG. 9.

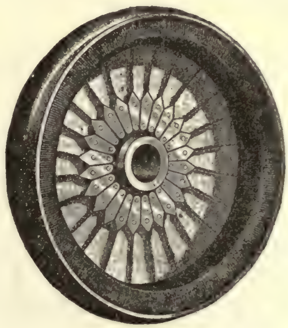


FIG. 10.

FIG. 8-10.—Diehl motor applied to sewing machines.

The wires leading to the motor pass up through the hollow casting of the frame, and are connected to a switch, by which the machine can be started and stopped at will. The fly-wheel is provided with a clutch or stop motion in connection with the shaft, so that it may be connected with the latter, or turned loose, as is common in sewing machines —the wheel being disconnected from the shaft when winding bobbins. This is accomplished by a turn of a thumb-nut at the rear end of the machine. By unscrewing this nut entirely, the armature may be slid out completely, so that it may be examined, should necessity require. This also exposes the field magnets and brushes, so that they can be easily gotten at for examination and attention.

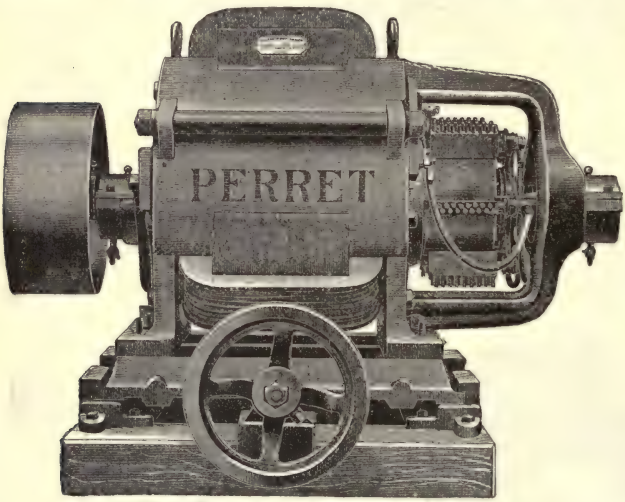


FIG. 11.—Twenty-horse-power motor.

The chief distinctive feature of the motors designed by Frank A. Perret is the lamination of the field magnet, which is built up out of thin plates of soft charcoal iron, stamped directly into their finished form, and clamped together by bolts in such a manner as to secure great mechanical strength. The armature core is also laminated, and the plates have teeth which form longitudinal channels on its periphery, in which the coils are wound. Fig. 11 is a side view of a 20 horse-power motor complete. Fig. 12 is a cross-section of magnets and armature showing magnetic circuit. It will be seen that the armature is a ring of comparatively large diameter, with longitudinal channels on its periphery, in which the conductors are wound and thus embedded in the iron, which is in such close proximity to the iron pole pieces that there is practically no gap in the magnetic circuit. The field consists of three separate magnets arranged at equal distances around the armature, each magnet having two pole pieces. The winding is such as to produce

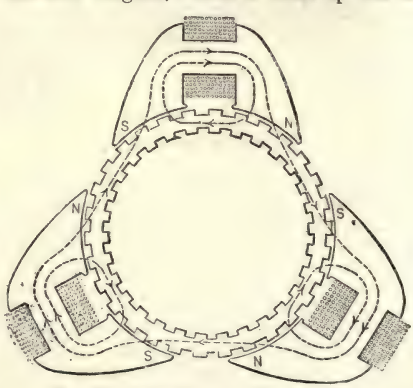


FIG. 12.—Perret motor. Cross section.

alternate north and south poles. The magnets are built up of plates of soft charcoal iron, which are shaped as shown in the diagram, and the magnet thus produced is of such a form that it may be readily wound in a lathe. A non-magnetic bolt passes through a hole in each pole-piece, and the plates are clamped together between washers and nuts on the same. These bolts also serve to attach the magnets to the two iron end frames, which are of a ring shape, and are bolted to the bed plates of the machine. The magnetic circuit is of unusually low resistance by reason of its shape, its shortness, which is shown by the diagram, and the superior quality of iron used. There is no magnetism whatever in the frame, bed, or shaft of the machine, as the magnets are supported at some distance from the frame by means of the non-magnetic bolts, and the armature is mounted on the shaft by spiders of non-magnetic metal.

The latest type of "C. & C." motor is shown in Fig. 13. The magnetic circuit is of the consequent type, which gives the greatest possible compactness of design. It is made in the circular form, having divided or parallel circuits, meeting at top and bottom, and passing together through the armature core. It consists of two cores, shaped like segments of a circle, bolted to pole pieces at both ends, surrounding the armature. The cores are of wrought-iron, planed off at the ends to an angle of 90°, so that when the machine is put together each core and pole piece forms a quadrant of a circle, the center of which coincides with the center of the armature shaft. This construction gives a very short magnetic circuit, free from corners or projections where leakage may occur, and makes the motor exceedingly compact for a given power. The pole pieces are of cast-iron, of much greater cross-section than the cores, the lower one being cast in one piece with the base. The poles enclose about 280° of the armature circumference. The field-magnet coils are wound directly on the cores by hand. The armature core is a drum made up of thin disks of sheet-iron, insulated carefully from each other. These are stamped with a hole in the center for the shaft, and after placing them on the shaft they are pressed together with great force. Iron arbor plates, keyed to the shaft at the ends, hold the disks firmly in position, and are themselves held by nuts screwed on the shaft. These disks are in addition held together by long bolts, whose heads are sunk into the arbor plates, thus ensuring an absolutely rigid and solid core. A modification of the Siemens winding is employed, and the wire is proportioned to carry an excess of current above the full load of the motor, without undue heating. The commutator is built up of cast tempered or of hard-drawn copper bars of tapering cross-section, beveled at each end. The insulation between the bars is of the best mica, made up of thin strips to the proper gauge. They are held together by steel collars, turned on one side to the same angle as the ends of the bars, and threaded to receive nuts, which are screwed up with great force against the collars, thus holding the bars firmly in place without allowing them to twist out of line. The sleeve and collars are carefully insulated from the bars by thick layers of mica.

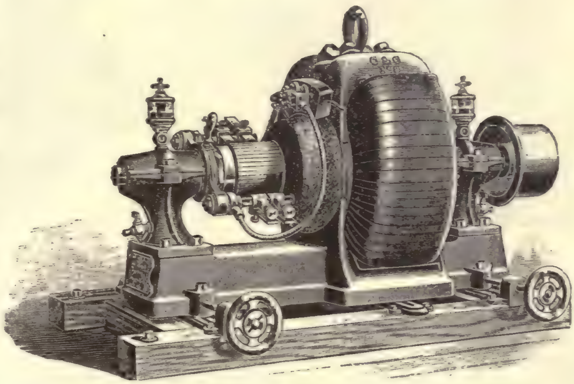


FIG. 13.—C. & C. motor.

The C. & C. small motor, shown in Fig. 14, is made up of interchangeable parts. The cores and pole pieces are drop forged, and afterward finished to gauge. The Gramme ring armature is shown in Fig. 15. The core is formed of punched sheet-iron semicircles, upon one side of which tissue paper is pasted. These semicircles are laid together, with the ends of alternate rings projecting at either edge of the built-up half cylinders, so that the edges of the two half cylinders so formed will interlock. The half circles and a rivet passed through, uniting them, lock the parts of a hinge. Upon this split ring is slipped a flat helix of wire, forming the entire winding of the armature in one layer, so that the operation of slipping it on is very simple. The wire used is flat, as shown in Fig. 16.

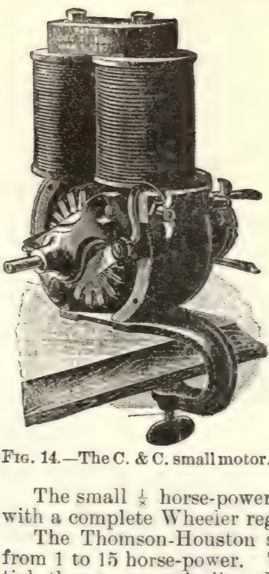


FIG. 14.—The C. & C. small motor.

The small $\frac{1}{8}$ horse-power C. & C. motor, shown in Fig. 17, is interesting as being made with a complete Wheeler regulator, by which it can be run at any speed.

The Thomson-Houston stationary motor, shown in Fig. 18, is made in different sizes, from 1 to 15 horse-power. The proportioning is such that, supplied with a constant potential, they are practically self-regulating as regards speed, though the load be varied from

nothing up to full power, or the reverse. At the same time the brushes on the commutator run without spark, and are not shifted in position during extreme changes of load on the motor. In other words, the non-sparking points of the commutator remain at one position without

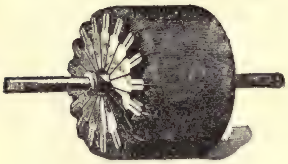


FIG. 15.—Gramme armature.

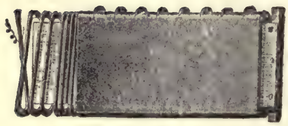


FIG. 16.—Winding.

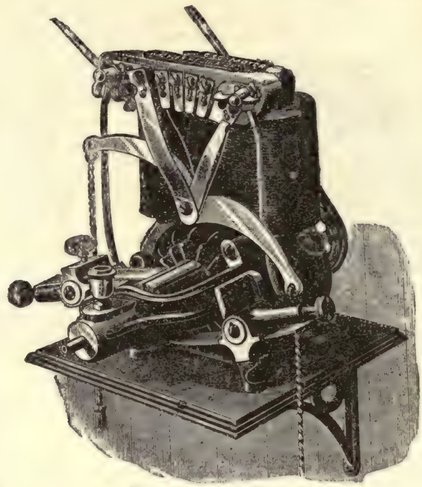


FIG. 17.—C. & C. motor.

change. As will be noted in Fig. 18, the poles of the field magnets—the bodies or cores of which are round in section—project upward and enclose the armature, the section of the core of which is nearly square. The winding of the armature is a modified Siemens arrangement, and the field magnet coils are in shunt to the armature. The armature core is so well laminated, and the resistance of the armature conductor is so low, that loss by Foucault currents,

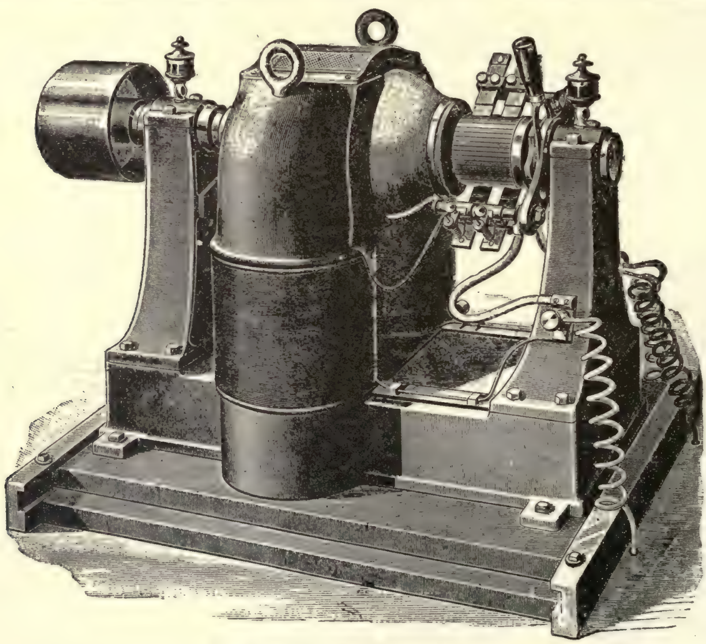


FIG. 18.—Thomson-Houston motor.

or local currents in the iron, and by internal resistance, is very light as compared with the output of the machine.

The motor shown in Fig. 19 was designed by Mr. William Hochhausen to regulate and to keep a constant speed with a variable load, with fixed brushes and without the interposition of external resistance. It has a single magnetic circuit, in which the armature is included. The regulation is effected by varying the intensity of the magnetic field to corre-

spond with the load. For this purpose the field coils are divided into ten sections, the ends

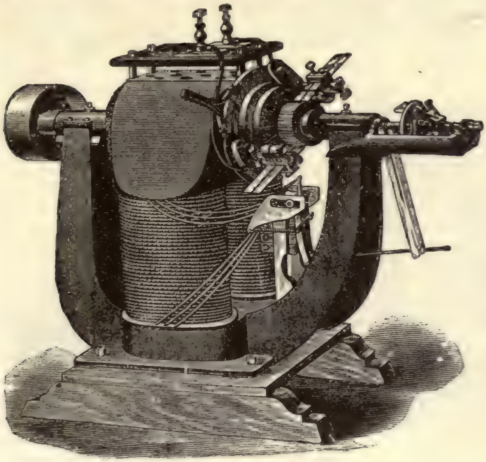


FIG. 19.—Hochhausen motor.

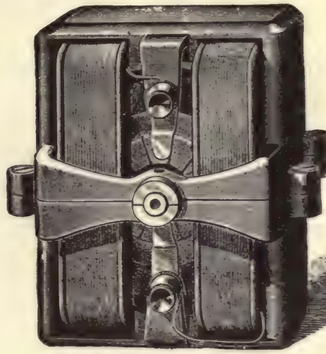


FIG. 20.—Hyer motor.

of which are brought to consecutive strips, shown at the side of and below the armature. The governor is of the centrifugal type, and acts upon an armature which extends downwardly and operates upon a contact maker which touches the various contact strips to which the field coils are connected. As the speed changes, these sections are cut in or out, varying the magnetic strength of the field accordingly.

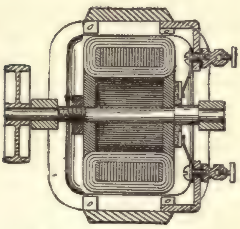


FIG. 21.—Hyer motor.

Figs. 20 and 21 show a perspective and sectional view of a motor designed by W. E. Hyer, in which both field coils and armature are surrounded by an iron shell, cast in two parts, having the bearings extending horizontally across the open ends. This construction closes the magnetic circuit so completely that no external magnetism can be detected.

The Stockwell motor, once largely used on arc-lighting circuits, is shown in Fig. 22. It is enclosed within a case, one end of which is removed so as to expose the interior. The magnets are of the converging, consequent-pole type, and form an integral part with the top and bottom of the casing. The two sides are cast separate and held together by screws. The armature, or, more correctly, the armatures, for there are two of them, are shown in Fig. 23. As will be seen, they are of the Siemens shuttle-wound type, and are placed at right angles to each other. The commutator has four segments, and the terminals of the wire on each armature are connected to opposite segments. The latter are not made parallel with the spindle, but are helical in shape, so that there is no break in the circuit at that point, since the brush passes the current to one armature before leaving the other. By this arrangement only one armature is in action at one time. Taking the one to the right, for example, it is at its maximum effect during the quarter revolution when the polar faces of the armature are approaching the pole pieces, and until they come directly opposite each other. During the next quarter revolution the armature is cut out of the circuit entirely; on the third quarter it again comes into the circuit until occupying the same relative position as in the first quarter; and, finally, in the fourth quarter it is again cut out. But it is evident that during each of these idle periods of the armature to the right, that to the left comes into circuit and goes through relatively the same cycle of operations.

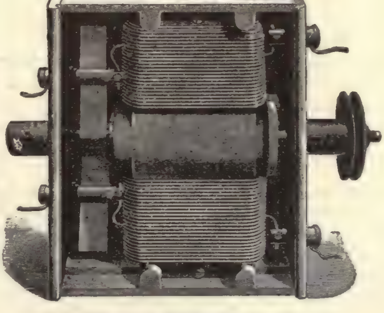


FIG. 22.—Stockwell motor.

The action is quite analogous to that in two steam engines coupled with their cranks at right angles to each other. While one is passing over the center, and practically doing no effective work, the other is in the position of maximum power, with the crank at right angles

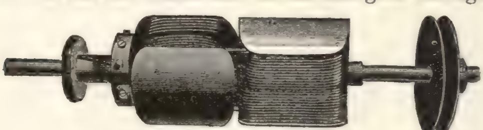


FIG. 23.—Stockwell armatures.

at the line of stroke. In both cases there can be no dead point, and the motion is smooth and continuous.

The Brush motor, which is illustrated in the engraving, Fig. 24, closely resembles the Brush dynamo, but the devices added to the machine for the purpose of securing steadiness

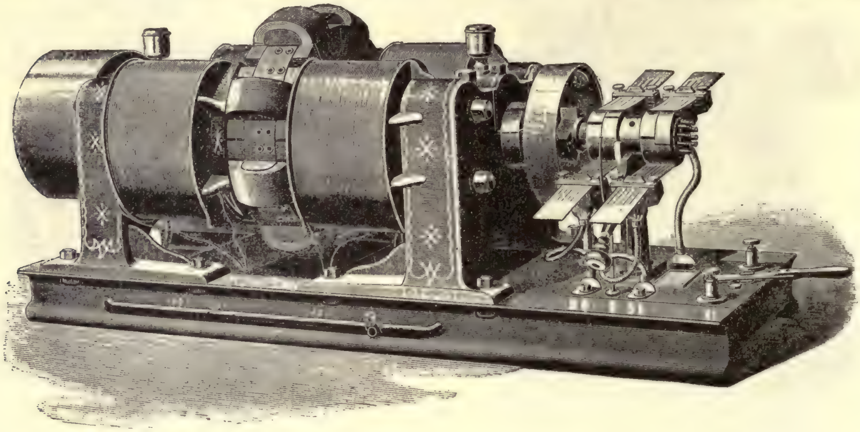


FIG. 24.—Brush motor.

of power and constancy of speed under all loads merit a detailed description. It will be seen that, mounted on the shaft between the commutator and the journal bearing, there is a cylindrical shell. This shell contains the governor by which the speed of the motor is maintained constant. The mode of regulation adopted by Mr. Brush consists in causing the governor to adjust the commutator automatically with relation to the brushes. To this end the commutator segments are mounted upon a sleeve on the shaft, so that they can be revolved to any desired extent under the influence of the governor.

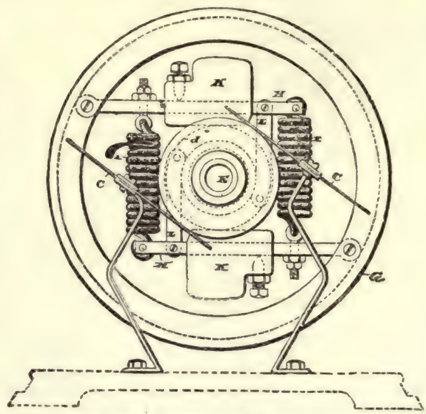


FIG. 25.—Governor of Brush motor.

The illustration, Fig. 25, shows the governor in detail. As will be seen, the commutator brushes, *C C*, remain fixed, and loosely mounted on the shaft, *E*, is the commutator sleeve, *a*, which turns freely. The commutator sections, *d*, are insulated from the sleeve, *a*, and are connected to the armature bobbins by flexible wires, so as not to interfere with the rotary adjustment of the commutator. To the inner periphery of the cylindrical shell, *G*, which is bolted to the shaft, the governor arms, *H H*, are pivoted. The inner free ends of the arms are connected to the opposite arms by means of spiral springs, *I I*. In addition, the arms carry each an adjustable weight, *K*. The links, *L L*, attached to the arms, *H H*, are connected to a disk upon the commutator sleeve. Hence, it will be readily understood that as the governor shell rotates with the pivoted weights, *K K*, the latter, by centrifugal force, will be removed toward the periphery of the shell, and, through the medium of the connecting links, *L L*, will impart a rotary movement to the commutator, varying its position on the armature shaft.

The action of the governor is precisely analogous to that in a steam engine. When in a state of rest, the springs draw the weights toward each other and maintain the commutator segments at the maximum point of effect with relation to the brushes. When current is switched on to the motor, the governor weights in their revolution are thrown outward and rotate the commutator, carrying the maximum points away from the contact points of the brushes and in the direction of rotation of the armature. This action decreases the effect of the driving current until a point is reached where the effect of the driving current is balanced by the load on the motor, and the speed of the latter remains constant. Now, should the speed of the motor be retarded by a decrease of current strength with no corresponding diminution of load, or by an increase of load with no increase of current strength, the governor balls will be retracted and drawn toward each other by the spiral springs, and thereby rotate the commutator in a direction opposite to the motion of the armature shaft, the effect of which is to move the maximum points on the commutator nearer to the brushes, and thereby increase the speed of the motor. On the other hand, should the speed of the motor

be increased above the normal rate, owing to an increase of current strength or to a decrease of load, the governor balls will be caused to recede from each other and rotate the commutator in the same direction as that of the armature shaft, and cause the maximum points on the commutator sections to be moved away from the brushes, and thereby decrease the speed of the motor. In this manner provision is made for all contingencies affecting the working of an electric motor.

At the Philadelphia Electrical Exhibition in 1884, Mr. Frank J. Sprague made the first public exhibition of several of his motors, which were run on a constant-potential circuit.

The Sprague motors may be divided into two classes, with subdivisions as follows :

1. *Variable-speed Machines*, comprising, (*a*) variable shunt ; (*b*,) Wheatstone bridge ; (*c*) standard railroad. 2. *Constant-speed Machines*, comprising, (*d*) variable shunt ; (*e*) long shunt ; (*f*) short shunt ; (*g*) combined shunts ; (*h*) distorted windings. The above are for operation on constant-potential circuits, to which class of work Mr. Sprague has mostly confined himself. There are a number of other forms for both constant-potential and constant-current circuits, particular description of which is unnecessary here.

In the variable-speed machines the object sought is, without introducing resistances external to the machine, to vary the potential differences existing at the armature terminals in a progressive manner from the maximum existing to zero ; to reverse the potential without breaking the continuity of the field or armature circuits ; to vary gradually the rotary effort of the armature, and, if necessary, also the strength of the field magnets. In a general way these results are accomplished by winding the field magnets in sections of variable cross-section and resistance, and arranging the armature circuit so that a greater or less number of the field-coil sections may be shunted to or put in series with it.

In the simplest form (Fig. 26) one end of the armature circuit is connected with a contact arm arranged to travel over a series of contact blocks connected with different sections of the field coils, and the other end of the armature circuit is connected with one end of the series at its junction with the supplying circuit ; as the arm moves over the successive contacts, the armature is shunted around a greater or less number of the sections of feed coils, and the difference of potential between the terminals of the armature circuit is varied from the maximum to zero. This method has been used to a considerable extent in introducing constant-speed machines into circuit without the use of a rheostat in the armature circuit.

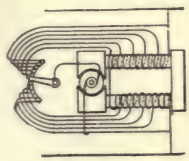


FIG. 26.—Motor.

In another form (Fig. 27) each terminal of the armature circuit is connected to a movable arm, both arms being made to travel along the contact blocks in opposite directions, so that the difference of potential at the brush terminals can be made to vary from the maximum to nothing, and then reversed, thus going through the full range of maximum difference in potential in one direction to the maximum in the other. In the third form (Fig. 28) there are two series of field-coil sections, the bights being brought to two sets of contact blocks ; the armature terminals are here also joined to two arms made to travel upon these contact blocks, so that the difference of potential at the armature circuit increases from zero to the maximum in either direction as required.

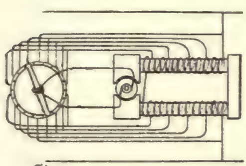


FIG. 27.—Motor.

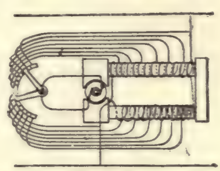


FIG. 28.—Motor.

In the standard street-railroad machine, the field magnets are wound with three sets of field coils of variable cross-section and resistances, which are in series with the armature. These coils are varied in relation from three in series to three in parallel, thus changing the total resistance of the machine, and varying the torsional effort and speed with any given current. For more detailed description of this method, see ELECTRIC RAILWAYS, Sprague system.

With the exception of this railway motor, the best known of the Sprague motors is that adapted to run at a constant speed on a constant-potential circuit under varying load, and for a time this was the only machine which had this quality. This machine is illustrated in Fig. 29. The method of regulating these machines was based upon the apparently paradoxical statement first enunciated by Mr. Sprague, that "to maintain the speed of a constant-potential motor, constant under varying loads, when the load increases, the field should be weakened ; and when the load is decreased, the field should be strengthened." This statement was founded on a differential investigation of the electrical expression for the work done. Without going into details of this investigation, Mr. Sprague's method of regulation consists, in brief, in strengthening the magnetizing effect of the field coils of a motor to decrease the mechanical effects, such as speed or power, or both ; and, *vice versa*, weakening this magnetizing effect to increase the mechanical effects ; and under varying loads the speed is maintained constant by an inverse variation of the strength of the field.

This may be accomplished in two ways : one, by varying the field circuit either by hand, or by a mechanical governor, which responds to any variation in the speed of the motor, and introduces or cuts out resistance in, or varies the arrangement of, the shunt field coils. This method, however, is not satisfactory, and Mr. Sprague's ordinary method of work-

ing is to make use of certain coils in series with the armature, and depending upon it, which coils have a magnetic action which is opposed to that of the main coils of the machine. There are three methods of arranging these coils, known as the long, the short, and the combined shunt methods. The long shunt is shown in Figs. 30, 31, and 32. By making these motors with large masses of iron in the field, and working with nearly a straight-line characteristic, these machines are constructed on certain laws known as Sprague laws.

Let f denote the resistance of the main or shunt field coil; m, the number of turns therein; r, the resistance of the differential or series field coils; n, the number of turns, and

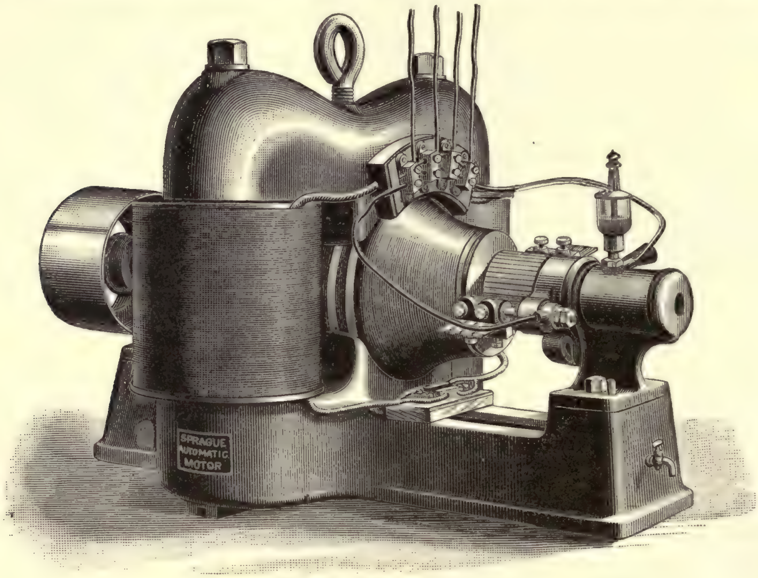


FIG. 29.—Sprague motor.

R, the resistance of the armature. Then for the long-shunt machine, the law of winding is expressed by the equation, $\frac{m}{n} = \frac{f}{R + r}$; that is to say, the number of turns in the shunt coil must bear the same ratio to the number in the series coil, as the resistance of the shunt coil bears to the sum of the resistances of the series coil and the armature. In the short-shunt machine, the law of windings is expressed as follows: $\frac{m}{n} = \frac{f + R}{R}$; that is to say, the number of turns in the shunt field must bear the same ratio to the number of turns in the series differential field, as the sum of the resistances of the shunt field and the armature bears to the resistance of the armature.

With these windings the motor will regulate itself perfectly at all potentials so long as the motor is worked with a straight-line characteristic, but it must be with an electric efficiency of over 50 per cent. A peculiarity in motors wound according to this method is that if the motor is standing still, and current is admitted to it with the circuits normally ar-

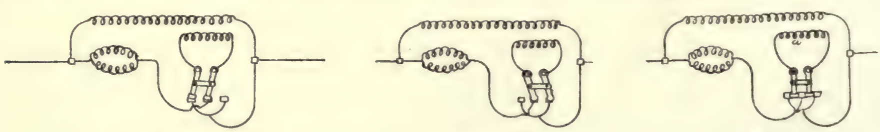


FIG. 30. FIG. 31. FIG. 32.

FIGS. 30–32.—Sprague shunt regulator.

ranged, the effect of the two coils is equal and opposite, and there will be no field excitation. This difficulty led to the introduction of a short-circuiting or reversing switch, which either cut out the series coil in starting the machine, or reversed it, making it a cumulative motor. In the four-pole machine designed by Mr. Sprague, more interesting from a scientific than a practical standpoint, now that motors have been raised to such high degrees of efficiency, a distorted winding was adopted, the series coil being put on two diagonally situated arms of the magnet; this resulted in distorting or shifting the resultant consequent field in a direction opposite to the distortion set up by the armature. The object of this was to keep the brushes at a fixed non-sparking point. In one railroad machine built by Mr. Sprague, this action was carried still further, the field magnets being wound with field

coils, having polar actions at right angles; the series coil was made cumulative on two arms, differential on the other two. Then with any variation in the strength of the shunt field, or any variation in either the strength or direction of the armature current, a variable shifting of the field was caused, in direction and degree opposite to that set up by the armature (Fig. 33).

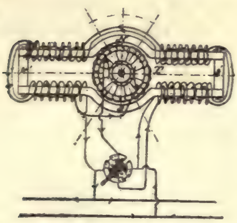


Fig. 33.—Sprague armature.

In the Sprague standard constant-speed motor, Fig. 29, the construction is simple and substantial. The bed plate carrying the armature bearings forms one pole; the crown of the machine another; and these two are united by a pair of field magnet cores. In this machine the length of core, the diameter of the bore, the external diameter of the field-magnet windings, and the length of the armature body, are all equal. The length of iron core is 1·6 the diameter. The capacity of the machine varies as the cube of the lineal dimensions, as it should in all good machines. These machines are used to a great extent in commercial operations.

An electric motor designed by Mr. N. H. Edgerton is shown in Figs. 34 and 35. The pole pieces, Fig. 35, are arranged each with three radial cores. on which the exciting coils are wound, and by which the fields are supported on the interior of a cylindrical iron shell which forms the framework of the motor, as well as the yoke-piece of the field magnets. The shell and pole pieces form a concentrically cylindrical structure. in the interior of which the armature revolves on a central shaft supported at either end by bearings situated centrally in the end caps or lids. These end caps may close the cylinder entirely or not, but usually one end is closed completely, while the other is left open, as shown, for easy access to the brushes and commutator. The armature, shown in section in Fig. 35, is polar, and consists of three helices, wound upon as many radial cores, set at equal distances upon a

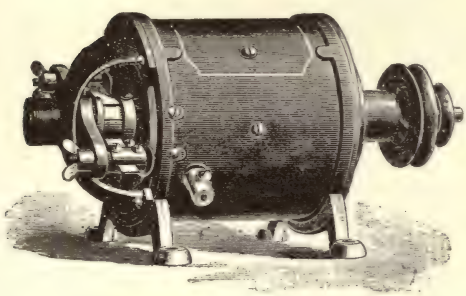


Fig. 34.—Edgerton motor.

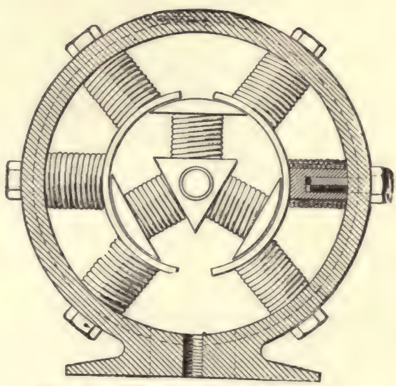


Fig. 35.—Edgerton motor. Section.

central prism of the same number of sides. Through the central axis of this prism, the shaft is placed longitudinally, and, as before stated, supported in bearings in the end caps of the motor. The outer or peripheral extremity of each of these cores is segmental in

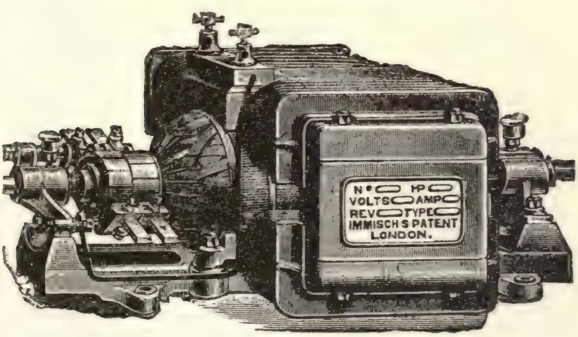


Fig. 36.—Immisch motor.

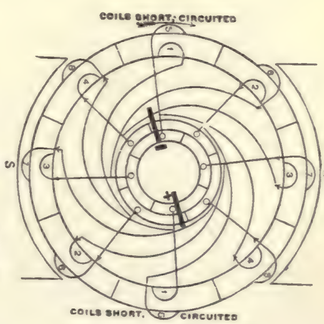


Fig. 37.—Winding.

shape, coinciding in curve with the inner concave surfaces of the pole pieces between which it revolves. The helices are wound parallel with the axis of the armature, as in the Siemens shuttle armature, and each is complete in itself. Similar ends of each helical wire are con-

nected with the commutator segments, of which there is one for each helix ; and the other similar ends are carried out to a common union, insulated from and carried upon the shaft.

The Immisch Motor is of English manufacture, and embodies some novel features, especially in the armature winding. Fig. 36 is a perspective view of the machine, and Fig. 37 a diagram of the winding. In the diagram only eight coils are indicated, although 48, 96, or more may be employed. The commutator is of the bisected type, and the coils are joined to

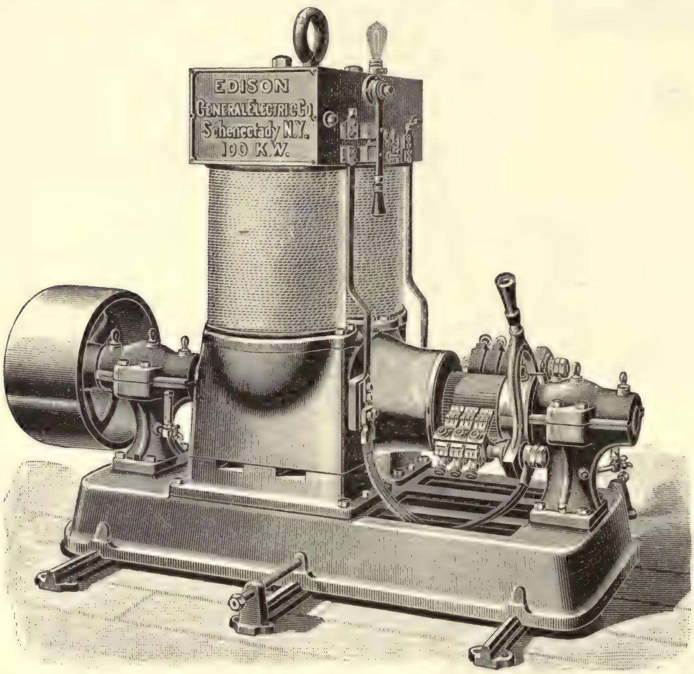


Fig. 38.—Edison motor.

two adjacent segments of the commutator on the two rings, of which one has an angular advance equal to one-half the width of the commutator bar. The two brushes, side by side upon the two rings, are connected together, so that only one pair is shown in the figure.

The Edison Motor is the Edison dynamo operated as a motor, with merely such changes as are necessary in reversing the direction of rotation of the armature. The differences between it and the incandescent dynamo of a similar size are scarcely discernible, and the windings are practically identical, except in the machines designed for special purposes. Fig. 38 shows the complete machine. The type and general appearance remain the same up to the 150 horse-power motor, corresponding to the larger Edison dynamos. Fig. 39 shows the diagram of connections, both of the motor itself and of the rheostat. The speed of the motors is very nearly that of the corresponding sizes of dynamo of the same voltage, and ranges from 2,100 revolutions per minute in the $\frac{1}{4}$ and $\frac{1}{2}$ horse-power motors, to as low as 360 in the 150 horse-power machine.

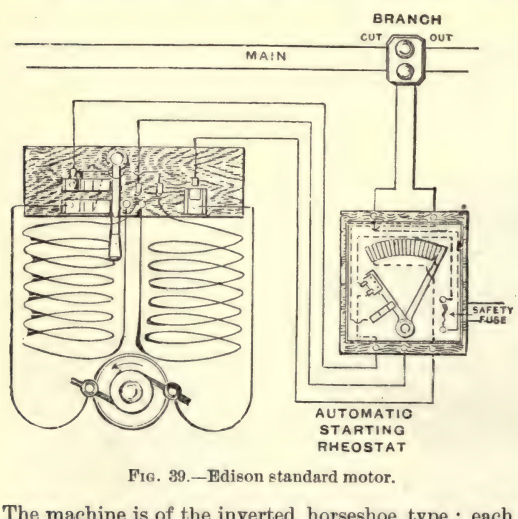


Fig. 39.—Edison standard motor.

Fig. 40 gives a view of the standard *Crocker-Wheeler motor.* The machine is of the inverted horseshoe type ; each pole piece is continuous with its magnetic core, of soft iron, drop forged exactly to its finished shape. These forgings are fitted into recesses in the main casting of the motor that forms at once the magnet yoke and the

support for the bearings. The armature is relatively of very large diameter, and, compared to the field, quite powerful. The armature is a Pacinotti ring with a comparatively small amount of wire wound upon it. The clearance of the armature is so small that the magnetic resistance of the air gap is exceptionally low, and the coils, sunk flush with the surface of the armature, are subjected to a very powerful induction. This construction, too, gives

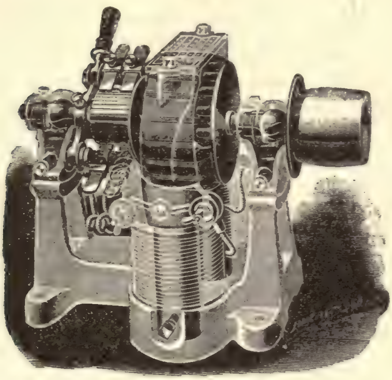


FIG. 40.—Crocker-Wheeler motor.

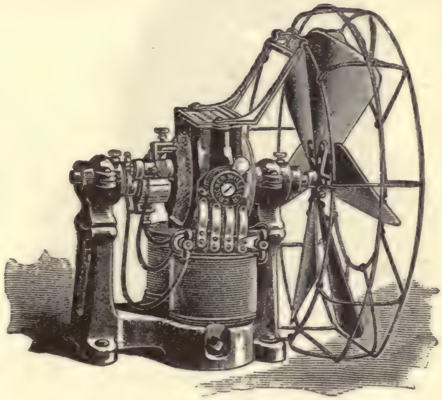


FIG. 41.—Fan motor.

almost complete immunity from burning out of the armature, as each section is isolated, and no two contiguous wires are subjected to any considerable difference of potential.

A little Crocker-Wheeler fan motor is shown in Fig. 41. It carries, usually, a 12-in. fan, and has come into very extensive use in offices, restaurants, and the like. On its pole piece will be noticed a starting switch, which is supplied to all the small motors for starting and stopping, and in some cases for regulating. This switch, when turned, first charges the field, then starts the armature through a resistance wound on the machine, and finally cuts out the resistance and gives the full current to the armature.

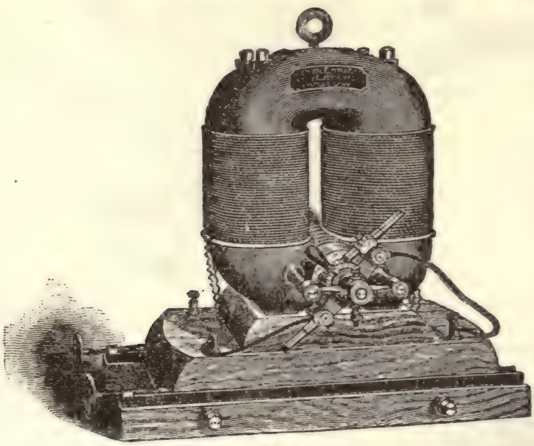


FIG. 42.—Eddy motor.

The Eddy Electric Motor, Fig. 42.—The magnetic circuit of this machine is of a modified horseshoe form, somewhat elliptical in shape, and of large cross-section. The material is soft cast-iron, and the motor is shunt wound with unusually fine wire. The armature is of the drum form, Siemens wound, as usual. It is wound with a comparatively small number of turns of rather coarse wire, giving a low armature resistance. All motors of above 7½ horse-power are wound with several wires in parallel for convenience and efficiency.

The United States Motor, Fig. 43, is a motor introduced by the United States Electric Lighting Co., and is a departure from the usual shapes of magnetic circuit, the form presented requiring but a single magnetizing coil, and being virtually an inverted horseshoe in shape, with the coils wound around the yoke. The magnetic circle is cast in two pieces, the joint being in the center of the magnetizing coil, and the two portions being held together by the bolts shown in the cut. The mechanical construction is exceedingly simple, as the field magnets form their own base by projections cast solid with them, and similar projections form a support for the bearings of the armature shaft. The switch for controlling the motor is placed directly on top of the pole pieces. The armature presents some peculiarities: it is a toothed drum of rather large diameter, the teeth very numerous and small, so that no trouble is encountered from the heating that usually follows the use of large projections in an armature. This construction accomplishes two ends. In the first place, it reduces the air gap to a very minute amount. In the second place, it simplifies winding the armature, for no special care need be taken in laying off the various sections as the armature is wound; it is simply necessary to take the size of wire used for that particular motor and fill the space between the teeth with it, thus forming an independent segment

of the armature. The mechanical advantage secured by this construction is that all the armature wires and bands lie beneath the surface of the armature, and are therefore completely protected from injury.

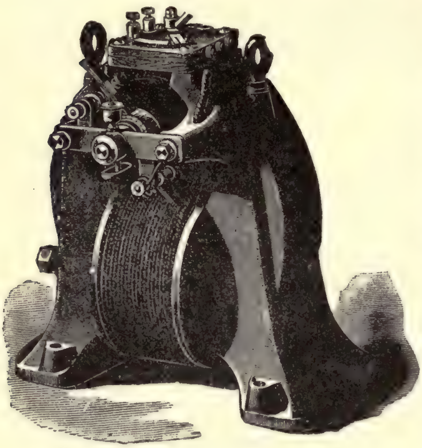


Fig. 43.—United States motor.

Alternating Motors.—*The Tesla Alternating Motor.*—Mr. Nikola Tesla was the first to build a practical motor employing currents of different phase, or what are now termed "polyphasal" currents. One of the types of the Tesla motor, as built by the Westinghouse Co., is shown in perspective in Fig. 44, and with its parts exposed in Fig. 45. It consists of a series of magnets built up of laminated sheet-iron and wound with two sets of coils, the ends of which are connected to the two binding posts shown. These binding posts form the only connection with the regular lighting circuits, with the addition of a single return wire. By the aid of this return wire, two alternating currents are sent through the field of the motor at the same time, the pulsations of the two currents being equal in strength, but the one lagging a quarter phase behind the other in the two sets of field coils, respectively. The effect of this is that a rapidly rotating polarity is given to the field, corresponding in period to that of the currents producing it.

The armature core of the motor is of the Siemens drum type, and it is wound with a comparatively few turns of heavy wire, the ends of which are soldered together, forming a closed circuit having no connection with the energizing current. The alternating currents in the field induce secondary currents in the armature, and by the attraction between these and the revolving polarity of the field, armature rotation is produced, the rate of rotation corresponding very nearly with that of the field. When no work is being done by the motor, the synchronism is exact, or nearly so, and very little current passes either through the armature or field; but as load is put on and the work increases, the armature tends to lag slightly, causing the passage of more current in proportion to the work done. The reaction between the armature and field is, therefore, similar to that between the primary and secondary of a converter when changes of lamp loads take place in the secondary circuit. The addition of the return wire for the motor circuit can be made easily, so as to adapt existing lighting circuits to motor work. The speed of the motor, as well as its direction of rotation, may be regulated by an ingenious adaptation of the converter principle, an adjustable "choking coil" arrangement being employed, which avoids the use of resistances and switches. The simplicity of the winding and general construction of the motor makes it unlikely to get out of

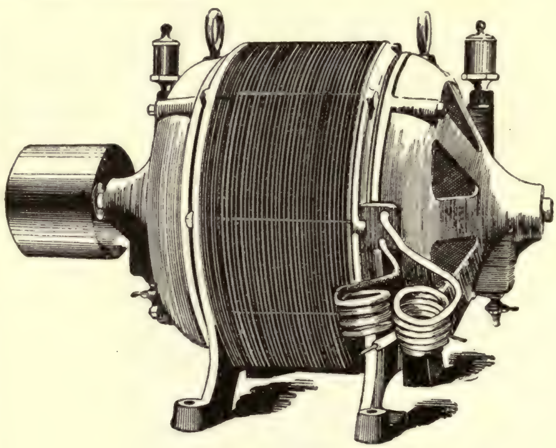


Fig. 44.—Tesla motor.

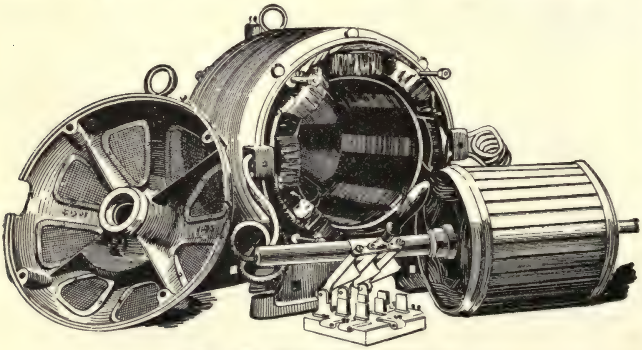


Fig. 45.—Tesla motor. Details.

repair. Thus the insulation of the armature is of no importance, since the current induced in it, though comparatively large in volume, has a potential of but a few volts, and often less than a volt, regardless of the voltage of the supplying circuits.

The Alternating Three-phase Motor, constructed by C. E. L. Brown, of Switzerland, is shown in part section in Fig. 46, and the armature winding in Fig. 47. Three armature circuits are connected, as in a Thomson-Houston armature, and the winding is so arranged that four rotating poles are produced. With 40 cycles the motor makes about 1,200 revolutions per minute. The motor takes 50 volts normally; a reduction to 30, or an increase to over 100, does not make any practical difference in the speed. Of course, in the first case, the heating of the armature wire is greater, and in the second the heating of the iron is increased. The magnetic field rotates, and is produced by the armature reaction, thus avoiding all sliding contacts. The field magnet is composed of a laminated ring with holes, in which are placed insulated copper bars. The free ends on both sides are connected by copper rings. It is not easy to imagine a more simple construction. The armature has 90 conductors of about 40 sq. mm. section. The weight of copper is 20 kg., the iron about 100 kg. The breadth of the armature is 20 mm., the outer diameter about 500. The rotating magnet carries 54 copper bars, with a section of 100 sq. mm. The weight of the copper is 15 kg.; that of the iron is 70. Recent trials in Oerlikon with this motor showed that it can easily supply 20 horse-power. The total weight of the motor is 420 kg.

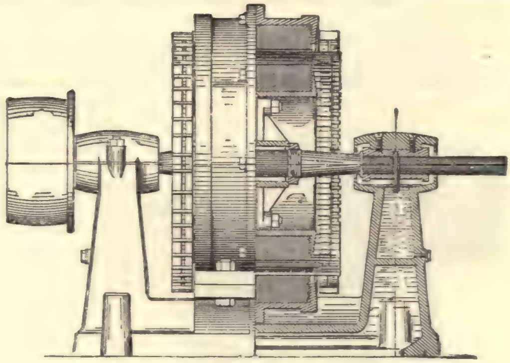


FIG. 46.—Brown three-phase motor.

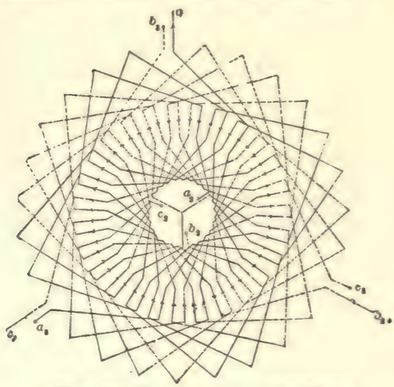


FIG. 47.—Brown armature winding.

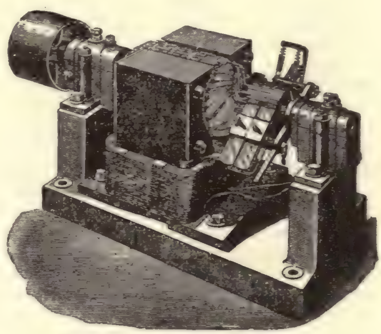


FIG. 48.—Rechniewski motor.

Multiphase motors have also been constructed by v. Dolivo-Dobrowolski, but they do not differ in principle from those of Tesla, described above. The motor employed in the transcommission of power experiments between Lauffen and Frankfort-on-the-Main, in September, 1891, was designed by Dobrowolski.

The Rechniewski Alternating-current Motor.—This motor, Fig. 48, designed by M. W. C. Rechniewski to work with alternating currents, does not differ from the ordinary continuous-current type, except that the field is of laminated iron. The armature is of the drum type, with Pacinotti teeth. For the sake of economy in the manufacture, both the armature and field-magnet cores are stamped out of one sheet. The following figures relating to a machine of 15 horse-power have been furnished:

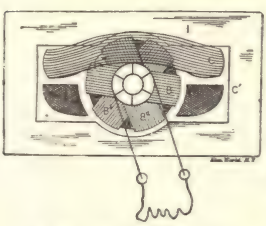


FIG. 49.—Thomson motor.

Volts at terminals, 115; current, 100 amperes; revolutions per minute, 1,400; diameter of armature, 8 in.; peripheral velocity in feet per minute, 2,800; weight of iron in field, 440 lbs.; weight of iron in armature, 108 lbs.; section of iron in field, 42·5 sq. in.; section of iron in armature, 33·5 sq. in.; induction in armature, 3,700,000 lines.

This motor is not, of course, self-regulating.

The Thomson Alternating-current Motor, invented by Prof. Elihu Thomson, is shown in Fig. 49. $C\ C^1$ are the field coils or inducing coils, which alone are put into the alter-

nating-current circuit. $I\ I$ is a mass of laminated iron, in the interior of which the armature revolves, with its three coils, B, B^2, B^3, wound on a core of sheet-iron disks. The commutator short-circuits the armature coils in succession in the proper positions to utilize the repulsive effect set up by the currents which are induced in them by the alternations in the field coils. The motor has no dead point, and will start from a state of rest and give out considerable power. A curious property of the machine is that at a certain speed, depending upon the rapidity of the alternations in the coil, C, a continuous current passes from one commutator brush to the other, and it will energize electro-magnets and perform other actions of direct currents.

Rankin Kennedy's Alternating-current Motor is shown in Fig. 50. It consists of two ordinary dynamos, with ring or drum armatures and laminated field magnets; both armatures are on the same shaft, their coils being connected together. One of the machines acts as the motor, the other taking the place of the commutator; there are no brushes and no commutator, and, therefore, an entire absence of sparking. The motor requires two currents, one at a quarter of a complete alternation in advance of the other; but it does not require any synchronizing, and it can start with load on from rest. The two currents at different phases are obtained from a transformer, or two line wires with a third for a common return, or from a coil wound on the field of one of the combined machines. Larger machines are made multipolar.

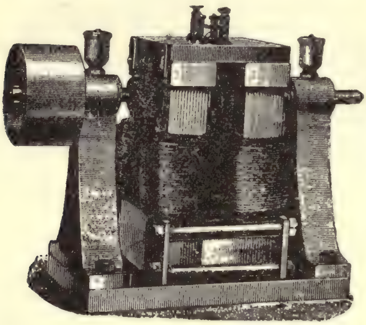


FIG. 50.—Kennedy's motor.

Tesla Motor with Condenser.—In the polyphasal motors above described the difference in phase is obtained by a specially constructed generator. But if the field or energizing circuits of a motor, in which the action is dependent upon the inductive influence upon a rotating armature of independent field magnets exerted successively and not simultaneously, be both derived from the same source of alternating currents, and a condenser of proper capacity be included in one of the same, that approximately the desired difference of phase may be obtained between the currents following directly from the source and those flowing through the condenser. The great size and expense of condensers for this purpose that would meet the requirements of the ordinary systems of comparatively low potential, however, are practically prohibitory to their employment in practice. This difficulty has been overcome by Mr. Nikola Tesla, in the apparatus shown in Fig. 51. Here $A\ B$ represent the poles of an alternating-current motor, of which C is the armature, wound with coils, D, closed upon themselves, as is now the general practice in motors of this kind. The poles, A, which alternate with poles, B, are wound with coils of coarse wire, E, in such direction as to make them of alternate north and south polarity, as indicated in the diagram by $N\ S$. Over these coils are wound long, fine wire coils, $F\ F$, and in the same direction throughout as the coils, E. These coils are secondaries in which currents of very high potential are induced. Mr. Tesla, as a rule, connects all the coils, E, in one series, and all the secondaries, F, in another. On the intermediate poles, B, are wound fine wire energizing coils, G, which are connected in series with one another, and also with the series of secondary coils, F, the direction of winding being such that a current impulse induced from the primary coils, E, imparts the same magnetism to the poles B as that produced in poles A by the primary impulse. This condition is indicated by the letters $N'\ S'$. In the circuit formed by the two sets of coils, F and G, is introduced a condenser, H, the circuit being otherwise closed upon itself, while the free ends of the circuit of coils, E, are connected to a source of alternating currents. As the condenser capacity which is needed in any particular motor of this kind is dependent upon the rate of alternation or the potential, or both, its size, and hence its cost, as before explained, may be brought within economical limits for use with the ordinary circuits. It is evident that by giving to the condenser proper value, any desired difference of phase between the primary and secondary energizing circuits may be obtained.

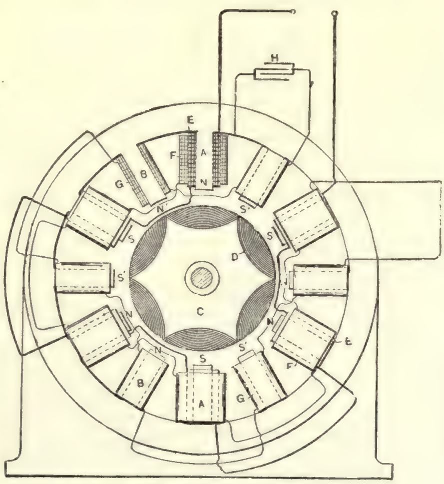


FIG. 51.—Tesla motor.

Motors embodying the above principles have also been constructed by Hutin and Leblanc, of France.

[For more detailed descriptions of electric motors, the reader is referred to the following works and papers : *The Electric Motor and its Applications*, Martin & Wetzler ; *Dynamo Electric Machinery*, S. P. Thompson ; *Electric Transmission of Energy*, Kapp ; *Electricity as a Motive Power*, Du Moncel ; also various papers by Kapp, Esson, Mordey, and others in the *Transactions* of the London Institution of Electrical Engineers, and papers in the *Transactions* of the American Institute of Electrical Engineers. Also the following periodicals : *The Electrical Engineer*, *The Electrical World*, *Electrician*, *Electrical Review*, *La Lumière Electrique*, *l'Electricien*. See also the index to periodical electrical literature, *Fortschritte der Elektrotechnik*, Berlin.]

MOWERS AND REAPERS. Both mowers and reapers of the side-cut type are now made preferably ; also "front-cut," the driver's seat being, in this form of the machines, attached at a point which is rearward as relates to the cutting line of the machine. The rear-cut mowers and reapers formerly used necessarily carried the seat, for purposes of balance, considerably in front of such a location, involving a measure of danger in case of a fall from the seat, as the natural tendency in the event of a collision of the finger bar with any obstruction to its progress, if by chance the driver is thereby unseated, is to throw him over to the cutting side rather than away from it. The mutilation or killing of mower and reaper drivers by the knives, once so frequent, is now, in consequence of the change, virtually unknown. The weight and cost of this important class of machines is also considerably reduced, while strength, effectiveness, and convenience are advanced by recent improvements.

The Walter A. Wood Mowing Machine, Fig. 1, drives the crank shaft from a cross shaft, whose pinion receives the power through a large internal gear, which receives power from a covered circular ratchet firmly attached to it and also to the axle. Pawls in the left driving wheel engage the ratchet, while pawls in the right driving wheel engage a similar ratchet at that end of the axle—the axle takes the torsional strain of the right wheel only. The frame is light steel tubing, jointed by deep, telescoping sockets, receiving side strain independently of bolts.

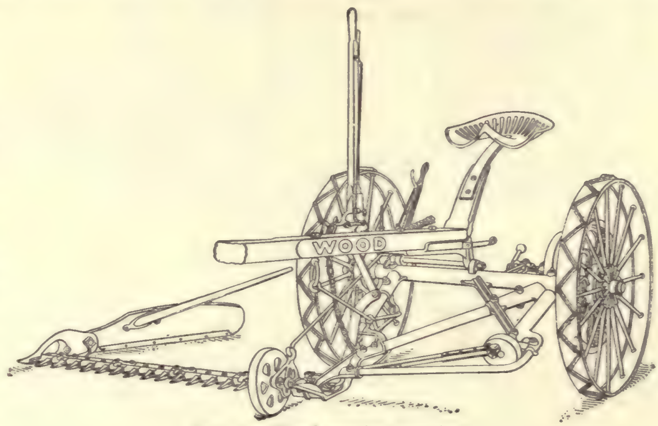


FIG. 1.—Wood mowing machine.

The steel wheel, with malleable iron hub plates gripping the spokes between them, and now generally adopted in some form for field agricultural implements, is used. The main gear and cross-shaft gear wheels rotate in the direction of travel, to avoid winding up grass. Speeding is attained with only two pairs of gears. No part of the draft is by the tongue, as a loose draft rod under the tongue imparts the draft of the team to the frame carrying the cutting apparatus on a line with its front portion, and hinging freely upon the axle at its rear line, where projecting arms sustain the cross-shaft support as a member of this hinged frame. The tongue and driver's seat are bolted to a separate socket, Figs. 2 and 3, which also sustains the fulcrum of the lifter lever, *a*. The lifter chain, *b*, hangs slack while the machine is mowing. When the lever is slightly depressed by the operator, it moves the lifter rod, *c*, upward, past the center on which the lever is pivoted, leaving the strong spiral spring, *d*, free to expand and swing upward the quadrant to which the chain, *b*, is hooked, thus aiding in lifting the weight of hinged frame and cutting ap-

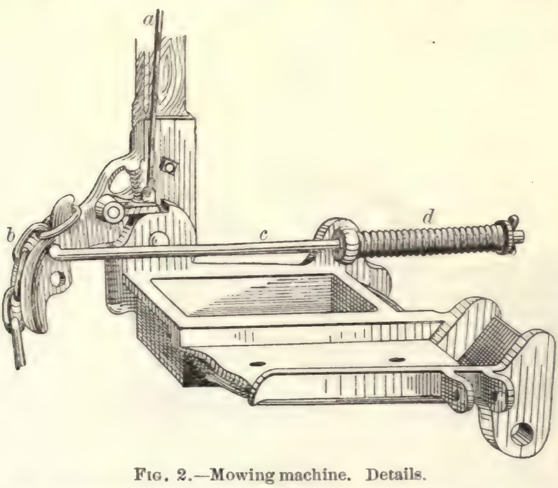


FIG. 2.—Mowing machine. Details.

paratus by supplementing the muscular effort of the operator by the action of the spring, *d*. The support for the lifter rod, *c*, is a stout swivel ring. The purpose of the device is to gain the supplemental spring-lift effect without sacrificing any of the independent floating action of the cutting apparatus, which is thus permitted to rest and ride along the variable surface of the ground while mowing, but is instantly controlled, suspended, and lifted by the chain, *b*, when it is desired to pass it over an obstruction, or move the machine forward when not in work. To prevent the lifter lever suddenly flying back by any jolt moving it so as to raise the front end of the rod, *c*, above the lever pivot, a check latch on the quadrant engages a notch in the bearing for the lever pivot as soon as the lever is pushed forward. Increasing magnitude of hay culture in the United States, and the immense areas of level land available, have changed mower construction as regards the standard width of swath—which width ten years ago was customarily from 4 to 4½ ft.—

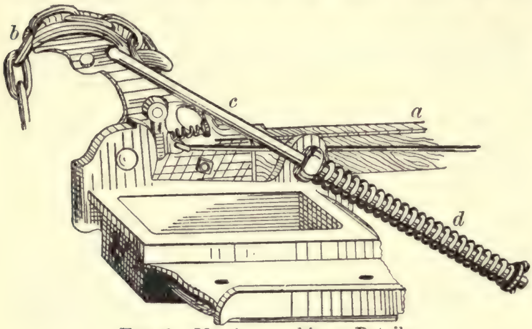


Fig. 3.—Mowing machine. Details.

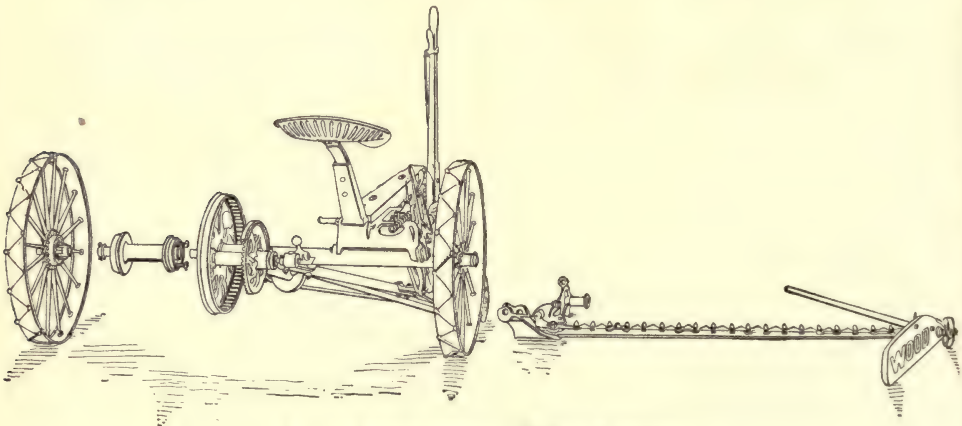


Fig. 4.—Mowing machine. Wide-cut adjustment.

until a swath 5 ft., 6 ft., and even wider, is the rule. This change has involved the introduction of a long finger bar, and the spring lift is a remedy for the difficulty found by the

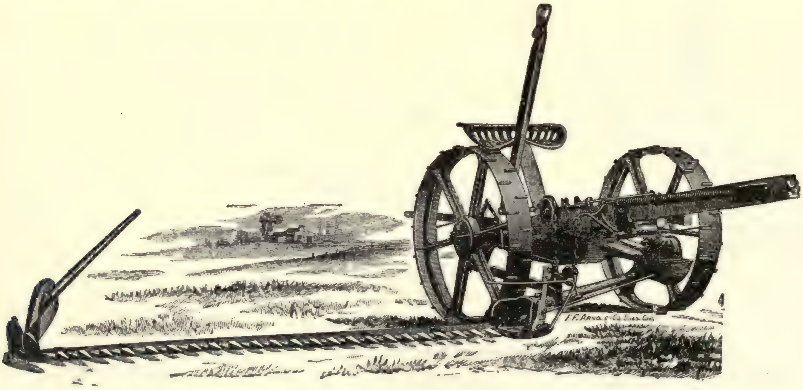


Fig. 5.—Emerson, Talcott & Co.'s mower.

operator in raising the long bar, with its increased weight and adverse leverage against the gag-iron universally used in some form at the inner end of the bar to facilitate high lift of the outer end. To make this mower available with long or short finger bars by suitable

tread gauge in either case, it may be fitted with the axle extension, *a*, shown in Fig. 4, which is a cast ratchet, like those of the driving wheels, extended into a tube containing a supplemental axle of suitable length, and which is interposed between the axle proper and the left driving wheel, steadying the machine by a wider separation of points of support, and maintaining the centrality of the draft line, as relates to resistance. The connecting rod, or "pitman," which drives the scythe, has tong jaws at each end, cupped to grip the ball-shaped scythe head ; also suitable bosses on the bearing for the crank pin on the forward end of the crank-shaft, swiveling the pitman so that it can not be cramped in the various positions assumed by the crank head and cutting apparatus, either while mowing rough land, or from the effect of rocking the finger bar with the tilting apparatus to raise or

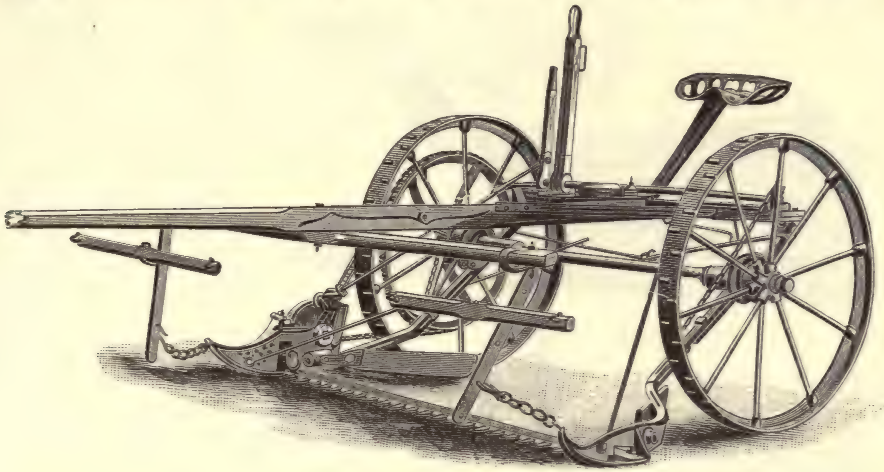


Fig. 6.—Mowing machine.

depress the points of the guard fingers, to suit the degree of closeness of cutting to the character of the crop and the roughness or smoothness of the ground. The zig-zag ribs seen on the driving-wheel face have the threefold effect of increasing traction for driving the cutters, resisting a tendency to side slip on inclined ground, and avoiding the jolt incident to separate transverse traction lugs when driving the mower over a hard surface.

Emerson, Talcott & Co.'s Mower.—A very wide-cut mower, Fig. 5, made by Emerson, Talcott & Co., of Illinois, is a representative of a class of side-cutting mowers in which much of the weight of the cutting apparatus and frame for crank shaft is sustained by a strong spring, which may be seen attached to the side of the tongue in front, and to a bell crank at its rear end, the crank hooked to a supplemental lift chain, so arranged that a constant pull is applied upon the upper end of an upright arm of the main shoe. The purpose is to keep the tension of the spring strong enough, by adjustment, to greatly relieve the friction of the finger bar, particularly at the outer end, when in work ; and also diminish the labor of the operator in moving the lifter lever to pass the bar over obstacles ; the contraction of the spring aiding him by an upward pull on the guide roller under which its chain passes. The arrangement increases the driving power of the wheel nearer the cutters by imposing part of the weight of the finger bar upon it, and is adopted to make wide swathing practicable under the convenient arrangement of mowing machines by which the cutting is done entirely on one side of the path traveled by the team and driving wheels. This mower may be used with a finger bar of 6, and even 7 ft. length. To overcome the tendency, which so long a bar would otherwise have, to crown in the center when largely upheld at the main-shoe end, the bar in manufacture is given a decided upward curve, which is neutralized as nearly as possible, in use, by the tendency of the outer end to sag. Unless the guard fingers maintain a straight line, the reciprocating knife can neither move freely nor present to the herbage a proper shear cut by contact of the cutting sections with the cutting edges of the guard fingers.

Fig. 7.—Lawn mower.

In the class of mowers represented by Fig. 6, the two driving wheels straddle the swath

just after it is cut, but one of the two horses drawing the machine must necessarily walk in the uncut grass to maintain centrality of draft. The scythe is vibrated by a short pitman, operated by a combination of chain and cog gearing from a chain wheel on the end of the main axle which in turn is revolved forward by both or either of the driving wheels, through the medium of the now universal hub ratchets. The main draft is by the tongue, but any desired portion of it may be transferred so as to act upon the cutter frame below, by an adjustable arrangement of suspended bars and chains, to ease up the cutter bar and its frame hinged upon the main axle. The object of this general construction is to attain great width of swath in connection with central draft. The mower may be used right hand or left hand.

Lawn Mowers.—Fig. 7 is the "Buckeye" lawn mower. It is provided with a hinged handle bar, and is self-adapting to the ground surface. Height of cut is determined at pleasure by adjustment of a rolling guide at the rear. The mowing-reel pinions are driven by internally toothed gear wheels, concentric with the ground wheels, in which they are ratcheted, so as to rest when the machine is backed by the operator. The hub of each ground wheel, projecting inward, forms a bearing for the hubs of the gear wheels, to condense the driving parts laterally, to avoid projections destructive to the bark of trees and shrubbery ; a front bar also fends them from the blades of the machine. Fig. 8 is a horse lawn mower, with which the lawn may not only be mown, but rolled, and also cleared of the mown grass, which, as it flies from the mowing reel, is caught in a pan attachment, carried on the mower.

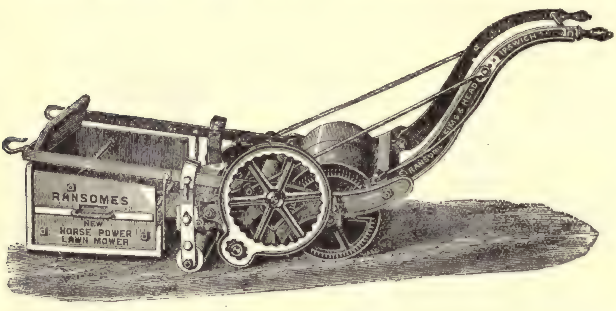


FIG. 8.—Lawn mower.

Naphtha Engine : see Engines, Gas.

Napper : see Cotton-spinning Machines.

NIAGARA, THE UTILIZATION OF. Few persons can have seen Niagara Falls without reflecting on the enormous energy which is there continuously expended. No one conversant with the national importance and commercial value of supplies of motive power can have passed the falls without some feeling of regret that so much available energy was wasted. To an engineer it must have occurred that the constancy of the volume of flow, the small variation of levels, the depth of the plunge over the escarpment, the nature of the rocks, the topography of the land, the proximity of railways, the access to the Great Lakes—all marked out Niagara as a site for an ideally perfect and unprecedentedly important water-power station.

The great system of lakes or inland seas, which extend half way across the continent, collect the rainfall from a vast territory, store it temporarily, and discharge it through the St. Lawrence into the Atlantic. Lakes Superior, Michigan, Huron, and Erie receive the drainage from a catchment basin of 240,000 square miles, whence it flows through the Niagara River into Lake Ontario, falling in level 326 ft. in a distance of 37½ miles. The average volume of flow is estimated at 265,000 cub. ft. per second. If the whole stream between Erie and Ontario could be used to drive hydraulic machinery, more than seven million horse power could be rendered available.

Fall of Level in the Niagara River.

Upper Niagara River	6 ft.
Rapids above falls	50 "
Falls	160 "
Rapids below falls	110 "

Immediately below the falls the river turns at right angles, and flows through a narrow gorge. The city of Niagara Falls occupies a flat table-land in the angle formed by the river. The variation during the year of the river levels is small, and is chiefly due to the action of wind. The ordinary variation of level does not exceed 1 ft. in the upper river, or 5 ft. in the lower river. The greatest authenticated changes of level in the lower river, due to ice blocks and other causes, amount to 13½ ft. rise above mean level, and 9 ft. fall below it. The rock consists of limestone and shale, in nearly horizontal strata, and is trustworthy for foundation works and tunneling, though timbering is required in the shale, and lining throughout, for a tunnel of large dimensions.

Early History of Water Power at Niagara.—The early traders erected stream mills in 1725. Later, the Porter family caused to be erected factories on the islands in the rapids above the falls, and obtained power from the river. Thirty years ago a much more systematic attempt was made to utilize the falls. A canal was constructed from Port Day, about

three-fourths of a mile above the falls, to the cliff above the lower river. In 1874, the Cataract mill was erected by Mr. Charles B. Gaskill. Since then other mills have been built along the cliff, taking water from the same canal, and utilizing altogether about 6,000 horse-power. These mills employ about a thousand operatives, and pay yearly in wages $350,000. They

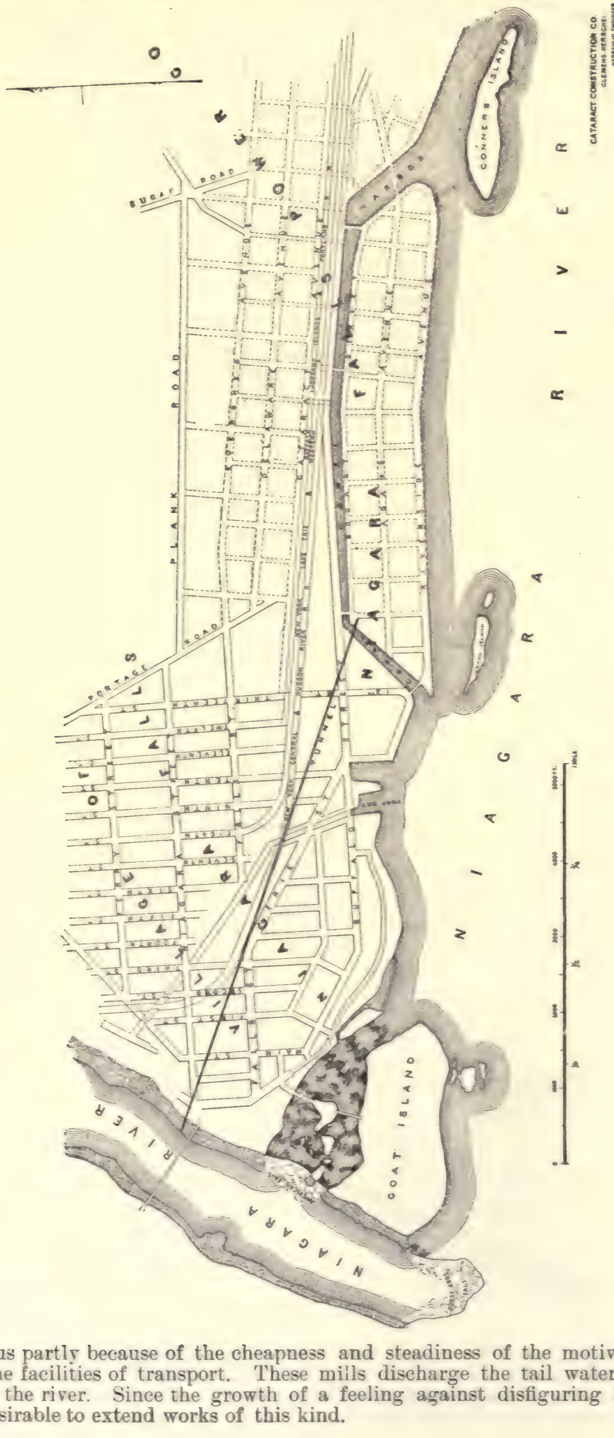


Fig. 1.—Plan of works at Niagara.

are prosperous partly because of the cheapness and steadiness of the motive power, partly because of the facilities of transport. These mills discharge the tail water on the face of the cliff over the river. Since the growth of a feeling against disfiguring the falls, it has become undesirable to extend works of this kind.

The idea of a better method of utilizing the falls is due to the late Mr. Thomas Evershed. He proposed to construct canals and head races on unoccupied land a mile and more above the falls, and to drop the water down vertical turbine-wheel pits into tunnels, discharging into a great main tunnel passing under the town of Niagara to the lower river. Apart from an

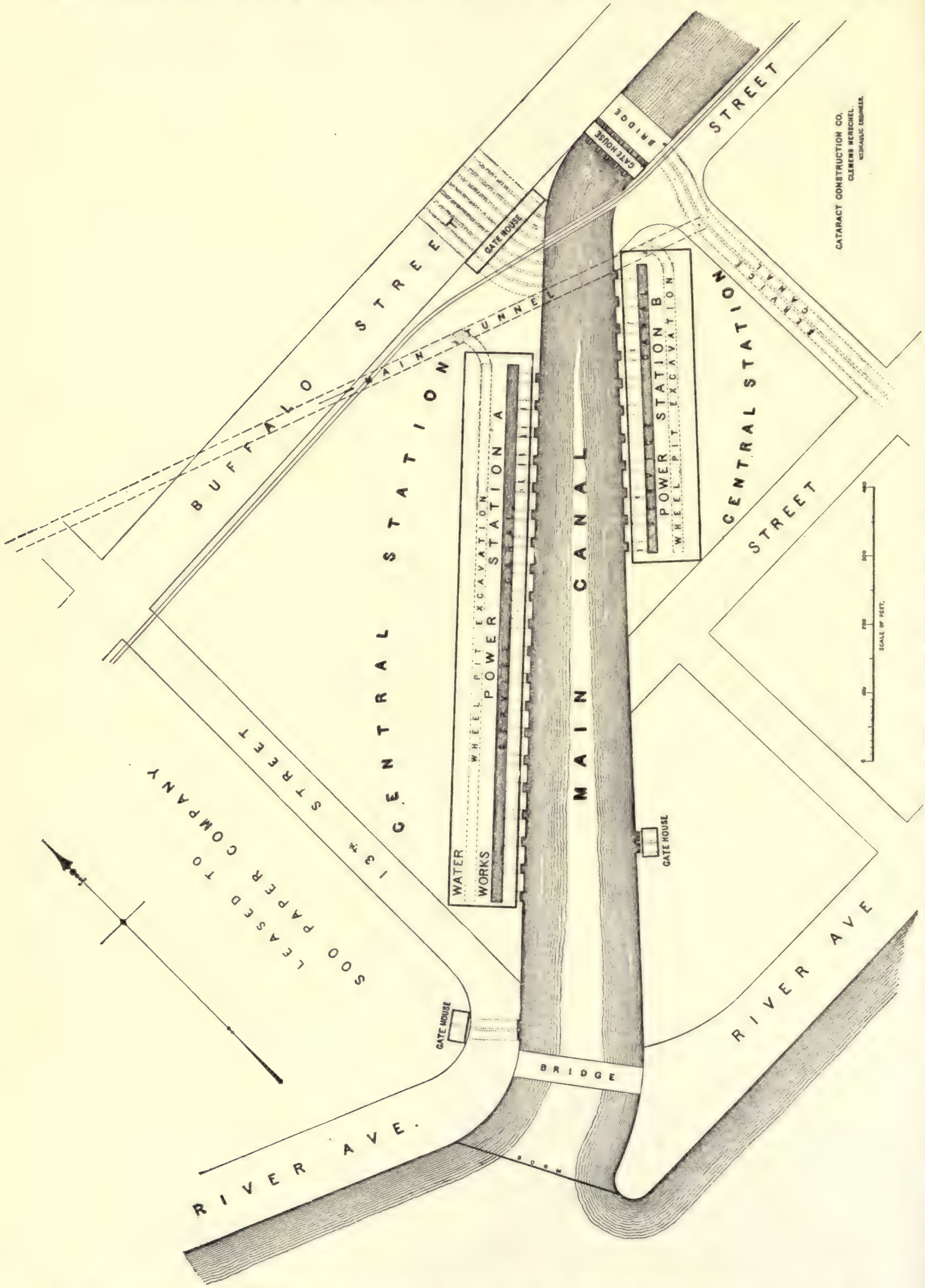


Fig. 2.—Primary power station

inappreciable diminution of the volume of flow over the falls, this plan avoids any damage to the scenery, and permits the utilization of a fall of 200 ft. It is essential to the plan of constructing a tail-race tunnel in the rock, that a very considerable amount of power should be utilized. Otherwise the proportionate cost of the tunnel would be excessive.

The Niagara Falls Power Co. and the Cataract Construction Co.—In 1886, the Niagara Falls Power Co. was incorporated by a special act of the legislature of the State of New York, for the purpose of utilizing Niagara in accordance with Mr. Evershed's

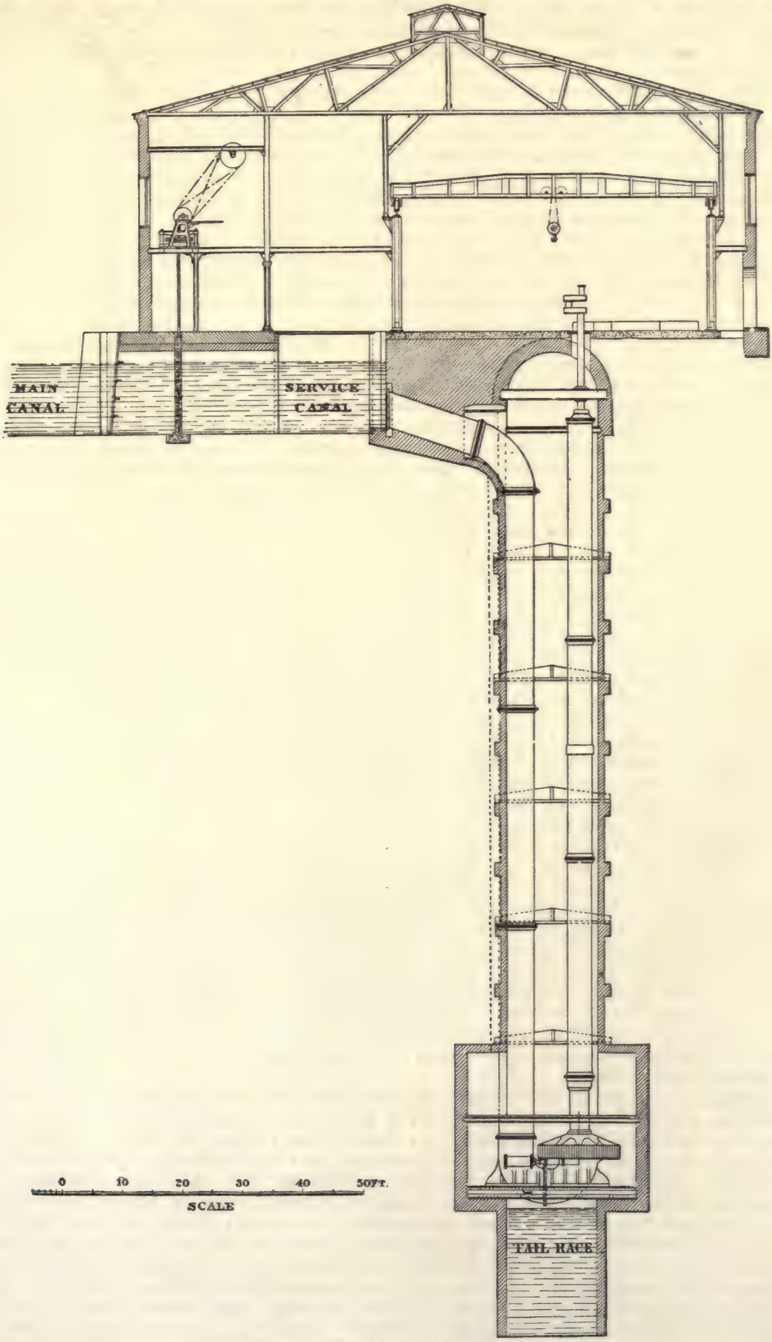


Fig. 3.—Wheel pit and discharge.

plans. (Laws of New York, 1886, ch. 83, 489 ; 1889, ch. 109 ; 1891, ch. 253 ; 1892, ch. 513.) Land extending along two miles of the shore above Port Day was obtained. Subsequently, in 1889, the Cataract Construction Co. was formed, the primary object of which is, under contract with the Niagara Falls Power Co., to execute all the works required. The

President of the company is Mr. Edward D. Adams; its vice-presidents are Mr. Francis Lynde Stetson and Mr. Edward A. Wickes, and its secretary and treasurer Mr. William B. Rankine. To advise and direct the works they have constituted a board of engineers, consisting of Dr. Coleman Sellers, Mr. John Bogart, Mr. Clemens Herschel, Mr. George B. Burbank, and Mr. Albert H. Porter. Col. Theodore Turrettini, who directed the works for utilizing the motive power of the Rhône at Geneva, is associated with them as foreign consulting engineer.

Already some 1,550 acres of land have been acquired, of which 1,000 acres will be reserved for manufacturing purposes, 150 acres for a terminal railway, and about 400 acres for a residential district. This latter part is being laid out on a systematic plan. The great main tail-race tunnel has been commenced, the contract having been given to Messrs. Rodgers & Clement. This tunnel will at the outset be 7,000 ft. in length, and 490 sq. ft. in section. It will be capable of discharging the tail water of turbines developing 100,000 horse-power. At the present time, 6,700 ft. of heading, and 6,251 ft. of bench have been driven. Arrangements have also been made for developing initially about 20,000 horse-power. Fig. 1 shows the position of the tunnel, the intake canal, and the proposed arrangement of the manufacturing quarter. Fig. 2 shows the arrangement proposed for the primary power stations. Fig. 3 shows a turbine wheel pit, with the arrangement of head race and discharge tunnel.

Systems of Power Distribution.—Probably to an engineer considering the conditions with any care, it would soon appear that the provision of a tunnel tail race and hydraulic machinery solved only half the Niagara problem, and that the least difficult and doubtful half. It is likely Mr. Evershed and those acting with him considered that nothing more was wanted for utilizing Niagara than the adoption of plans already in successful operation in the United States, but on a more gigantic scale. It does not seem to have been at all recognized at first that the magnitude of the Niagara scheme was itself a condition rendering the older methods of utilizing water power, if not physically impracticable, at least of doubtful commercial success. Nowhere else in the world has water power been utilized on so great a scale as in the United States. The towns of Lowell, Lawrence, Holyoke, and Manchester owe their very existence as manufacturing centers to water power. At these towns, less favorably situated than Niagara, a fall was artificially created by building a dam across a river; from the up stream side of the dam, water was supplied to mills by canals, and they discharged it below the dam by other canals. The mill owners constructed the requisite machinery, and the water-power companies obtained a return on their expenditure by a rental based on the quantity of water supplied. Generally, in these towns the fall utilized is not very great, so that no very expensive excavations are required for the wheels; also the distribution of the water and assessment of the rental presents no special difficulty. The cost for the water supplied varies in different towns; on the average, the rental appears to be from $14 to $18 per annum per effective horse-power delivered from the turbine shaft. The additional charge for interest on capital expended by the mill owner in hydraulic machinery, repairs, wages of attendants, etc., would appear to be about $8 per horse-power per annum. So that the total cost of an effective horse-power to the mill owners appears to be from $22 to $28 per annum.

At Niagara no dam has to be constructed. On the other hand, the tail-race tunnel is a work of such a kind that its cost per horse-power utilized diminishes very much as the whole amount of power dealt with is greater. The actual section of the tunnel is 490 sq. ft., and it is intended to discharge 8,800 cub. ft. per second. Taking the effective fall, after deducting all possible losses, at 160 ft., and assuming moderately good turbines, this quantity of water will yield 100,000 effective horse-power. The cost of the tunnel amounts to less than $10 per effective horse-power. A rock tunnel lined with brick is practically as durable as the rock itself, and the interest on this sum is but an insignificant item in the charge for power if the tunnel is fully worked. With 8,800 cub. ft. per second, the velocity in the tail-race tunnel will be only 18 ft. per second if it discharges full bore, or perhaps 25 ft. per second if it discharges as an open canal. Neither of these velocities is too great for a masonry lined rock tunnel.

The construction of a tail-race tunnel imposes, therefore, no difficulty in the way of utilizing Niagara, provided it is undertaken on a large scale. It is only when the details of a system of surface canals for distributing so enormous a volume of water to different consumers are considered, and the cost and complexity of a system of secondary tunnels to re-collect the water from different consumers, and discharge it into the main tunnel, that a doubt arises as to the practicability of methods in which each consumer takes the water required for power on his own land, and constructs his own wheel pits and machinery. Part of the water power at Niagara will undoubtedly be utilized in this way, especially on land nearest adjacent to the main tunnel. In the case of an industry requiring a very large amount of power, it will be practicable and economical for manufacturers to take the water and construct wheel pits, necessarily 180 ft. in depth, and the machinery for utilizing it. But such a method is little adapted for smaller factories. It would probably be a long time before at Niagara a sufficient number of large manufacturers could be attracted to utilize in this way 120,000 horse-power.

Obviously, it would greatly economize the capital expenditure to develop the power in one or more central stations by turbines of large size, of uniform type, under common management. It would equally facilitate the sale of the power if manufacturers could take it in any required quantity, without the trouble of sinking wheel pits or erecting turbines. Once

given the means of conveying and distributing *power* instead of *water*, a very important extension of the original project becomes possible. In addition to supplying manufactures attracted to Niagara, the power may be taken to existing manufactures in Buffalo and Tonawanda.

Various systems of power distribution to different consumers have been tried during the last twenty or thirty years. Quite recently great success has been achieved in some of these systems, and a very short account of the methods adopted will serve to indicate both the nature of the problem at Niagara, and the extent to which past experience affords guidance in its solution.

The International Niagara Commission.—To secure impartial examination and competent discussion of projects for the utilization of Niagara, an International Niagara Commission was formed, and a sum of £4,500 was placed in the hands of the commission, to be awarded, partly in premiums to all invited engineers who sent in plans of sufficient importance, partly in prizes to those projects judged to be of the highest merit. The commission was constituted as follows : Sir William Thomson, F.R.S., LL.D., *President;* Dr. Coleman Sellers, M. Inst. C. E.; E. Mascart, Membre de l'Institut, Paris ; Col. Theodore Turrettini, director of the works for the utilization of the motive power of the Rhône at Geneva ; Prof. W. C. Unwin, F.R.S., *Secretary.*

For the information of the competitors, plans and photographs were prepared, and a detailed letter of instructions was drawn up. Competitors were asked to prepare plans and estimates for developing an effective power of 120,000 horses by hydraulic machinery, and for the transmission and distribution of this power partly to a manufacturing district on the land of the company, partly to Buffalo and Tonawanda. The arrangements adopted were successful. A large number of projects were received from mechanical and electrical engineers of the greatest reputation. Many of these were worked out with extraordinary care and completeness. In some cases the accompanying memoir formed a scientific treatise, and contained information of the greatest value. The following is a *résumé* of the projects received :

Name.	Kind of hydraulic machinery proposed.	Method of distribution proposed.
Cuenod Sautter & Co., and Faesch & Piccard. (Geneva.)	(*a*) Impulse turbines of 2,500 horse-power, with horizontal shafts, in underground galleries, coupled direct to dynamos by Raffard couplings. (*b*) Impulse turbines of 2,500 horse-power in wheel pits, with vertical shafts, driving machinery above ground. Turbine shafts with hydraulic support, hydraulic relay governors, and sluices worked hydraulically.	(*a*) One hundred dynamos of 1,250 horse-power each, and 10 in reserve, coupled in pairs in series. Distribution at Niagara in two circuits of 1,000 volts and one of 500 volts. Overhead conductors, with spans of 200 yards. For Buffalo, 10 dynamos in series, giving 16,000 volts. Motor transformers in Buffalo, giving four circuits at 1,000 volts, and two at 500 volts. System, continuous current at constant potential. (*b*) Dynamos of 530 and 4,735 volts. The manufacturing district supplied with four circuits at 4,500 volts and two at 500 volts, and a neutral wire. For Buffalo, two conductors at 4,500 volts, and a neutral wire. Compensating motor transformers at Buffalo.
Vigreux & Levy. (Paris.)	(*a*) Axial-flow pressure turbines of 2,500 horse-power, coupled in pairs on horizontal shafts in underground galleries. (*b*) Inward-flow pressure turbines of 5,000 horse-power. (*c*) Outward-flow pressure turbines of 5,000 horse-power.	Dynamos with twin armatures, continuous current, 2,500 horse-power, 330 amperes, 5,000 volts. Dynamos for exciting current at 500 volts. Iron-braced girders carrying naked copper conductors overhead, in spans of 100 feet. Motor transformers for reducing potential.
Hillairet & Bouvier. (Paris.)	10,000 horse-power turbines of Girard type, with vertical shafts.	Dynamos of 10,000 horse-power, directly coupled to turbine shafts, with Raffard couplings. Each dynamo gives 7,000 amperes at 1,000 volts. The dynamos used independently or coupled in series, according to the distance of transmission. Motor transformers for low-tension circuits.
Popp & Riedler. (Paris and Berlin.)	For projects (*a*) and (*b*): Axial-flow pressure turbines of 5,000 horse-power, from Rieter of Winterthur. Horizontal shafts in (*a*) and vertical in (*c*). For project (*b*). Outward-flow pressure turbines, with horizontal axis, by Nagel & Kaemp, of Hamburg. (*c*) Similar turbines, with vertical axis.	(*a*) Underground, directly driven compound air compressors, at 80 revolutions per minute. (*b*) Underground air compressors, at 150 revolutions per minute. (*c*) Overground compressors, at 80 revolutions per minute. (*d*) A similar arrangement. 25,000 horse-power transmitted to Buffalo at 114 lbs. per sq. in., giving 88 lbs. per sq. in. in Buffalo, through two mains 2¼ ft. diameter. Or 75,000 horse-power, transmitted through the same mains with 199 lbs. per sq. in., giving 110 lbs. per sq. in. in Buffalo. Compressors, compound, with Riedler system of controlled valves. Efficiency estimated at 85 per cent., every loss in compressors and motors and transmission to Buffalo included.

Name.	Kind of hydraulic machinery proposed.	Method of distribution proposed.
Deacon & Siemens Bros. (London.)	Inward-flow pressure turbines of 2,500 horse-power, with horizontal shafts, directly coupled to dynamos in underground galleries.	Continuous-current dynamos of 2,500 horse-power, giving a constant current of 400 amperes, and potential varying up to 4,500 volts. Conductors, insulated cables. Low-tension current obtained by motor transformers.
Pearsall. (London)	Air directly compressed by pressure due to fall in cylinders, with valves worked by pressure engines. Air pressure, 150 lbs. per sq. in. Pressure water supplied in the same way.	
Lupton & Sturgeon. (Chester and Leeds.)	Inward-flow pressure turbines of 3,750 horse-power, with vertical shafts.	Single-acting air compressors delivering at 5¼ atmospheres. Compressors geared to turbine shaft. Air main to Buffalo, 10 ft. diameter, decreasing to 7 ft. Electric lighting station at Buffalo worked by compressed air.
Ganz & Co. (Buda Pesth.)	Partial-flow impulse turbines of 5,000 horse-power, with vertical shafts in wheel pits, directly coupled to dynamos placed above ground. Governor to turbine sluices.	Alternate-current dynamos working at 5,000 horse-power, 336 amperes, 10,000 volts. Overhead conductors on iron supports 50 metres apart. Transformers at Buffalo to reduce potential to 2,000 volts. Separate exciting current dynamos at 200 volts.
Escher Wyss & Co. (Zurich.)	Axial-flow pressure turbines on vertical shafts in wheel pits. Power varying from 2,500 to 10,000 horse-power.	The Oerlikon Electrical Co. were to have sent designs of dynamos, but were too late to compete.
Rieter & Co. (Winterthur.)	Pressure turbines of 2,000 horse-power on vertical axes. Pressure turbines of 2,500 horse-power on horizontal axes. Pressure turbines of 5,000 horse-power on horizontal axes.	Wire-rope transmission only partially worked out.
Vigreux & Feray. (Paris.)	Partial-admission Girard turbines, of 34 ft. diameter and 2,500 horse-power, with horizontal axes.	Direct-driven hydraulic pumps, giving pressure water at 710 lbs. per sq. in. A pair of steel distributing mains 24 in. in diameter from each set of 12 pumps, delivering 10,000 horse-power.
Pelton Water Wheel Co. (San Francisco.)	4,000 horse-power and 2,000 horse-power Pelton wheels, with multiple nozzles and governed sluices.	Air compressors, pressure pumps, and dynamos.
George Forbes. (London.)	Turbines (not designed).	For Niagara, alternating or continuous dynamos at 2,000 volts. For Buffalo, alternating dynamos at 2,000 volts, the current transformed to 10,000 volts. Bare copper conductors on posts. Synchronizing motors and motor transformers for continuous current at low potential.
Norwalk Ironworks Co. (South Norwalk, Conn.)	Pelton wheels of 5,000 horse-power.	Compound air compressors, delivering at 147 lbs. per sq. in.

The prizes were awarded as follows for projects combining the development of power and its distribution : First prize not awarded. One second prize, to the project of Messrs. Faesch & Piccard, Geneva, and Messrs. Cuenod Sautter & Co., Geneva. Four third prizes, to the projects of Mr. A. Hillairet and Mr. Bouvier, Paris ; Mr. Victor Popp, Paris, and Prof. Riedler, Berlin ; Prof. L. Vigreux, and Mr. L. Levy, Paris ; the Pelton Water Wheel Co., San Francisco, Cal., and Norwalk Ironworks Co., South Norwalk, Conn. For projects for the hydraulic development of the power, prizes were awarded as follows : First prize, to the project of Messrs. Escher Wyss & Co., Zurich. Two second prizes, to the projects of Messrs. Ganz & Co., Budapest ; Prof. A. Lupton, Leeds, and Mr. J. Sturgeon. For projects for the distribution of the power, no prize awarded.

The Tunnel.—Since the invention of machine drills, the question of drilling for the excavation of rock tunnels has become subordinate to the question of the removal of "muck" (broken rock) when rapid driving is required. It is necessary that very little time be lost before and after firing the blasts, so that the muckers can work the longest possible time. To attain this end, powder must be selected which is free of obnoxious gases, and runways for barrows or cars must be arranged so as to require but one handling of material.

The plate shows method in use during construction of Niagara Falls power tunnel. Here the tunnel was driven in two benches, or, more correctly, one heading and one bench. Muck was taken directly from the heading in cars and dumped into cars on lower floor of tunnel, without interrupting the working of the lower bench. This is the usual practice now, when driving tunnels over 10 ft. in height. Several modes of supporting the runways, however, have been used, but we know of none so perfectly adapted to saving of time as mode shown in sketch. In timber section the hangers were put in about 8 ft. apart. The tongs were made of 1½ in. × ½ in. Norway iron, steel pointed. Rods were 1 in. in diameter, with hooks at both ends ; the bars were of wood, 8 in. × 8 in. 2 in. × 12 in. planks, 24 ft. long, were used for the bridge or floor, on which a track, fastened together at proper gauge, was laid. The advantage of this scaffold was that it was easily put up, and that it did not require to be taken down when blasting the bench. When blasts were made, the planks

which connected the upper bench with the first bar were pulled back onto the bench, leaving the balance of scaffold free to swing in any direction. After the blast the planks were run out into place, and the time lost was hardly noticeable. While the scaffold was in use it was necessary to keep it from swaying from side to side. This was done by using iron rods fastened to eyes, bolted to the bars, so that they could be extended to projecting points on side of tunnel. One of the headings where these scaffolds were used was through hard limestone, which broke with sharp cutting edges. Eight bars were used from start to finish.

Conclusions.—Some idea can now be formed of the importance of the work in progress at Niagara, and as to the extent to which there still remain questions which can only be answered by experience. It has been stated that the tail-race tunnel, the greatest of the constructional works required, together with the great surface inlet canal, are already in construction. Some land has already been leased with the right to take water for 3,000 horse-power, and probably twice as much subsequently. Machinery for a first instalment of the generating plant, comprising turbines of 10,000 of horse-power, air-compressing machinery for 5,000 horse-power, and electric machinery for 5,000 horse-power, has been contracted for. The two systems of power transmission which are most available will thus be tried side by side, and extensions can be made in whichever direction seems advisable after some experience is gained, and as fast as the demand for them arises.

The Niagara project differs from any similar undertaking primarily in the magnitude of the work undertaken. But it is precisely this which has led to the adoption of plans of power distribution as a supplement to water distribution. Such plans, on a smaller scale, it is true, but in conditions in many respects greatly more difficult, have been carried out successfully in Europe. Indeed, with respect to the distribution of power within a distance of four or five miles from the power generating station, it may be asserted that the distribution can be effected either by compressed air or by electricity, with certainty and economy, by methods well understood, by appliances which have been already used and tested in practical work, and without at any point having to encounter any unforeseen difficulty. Compressed air has the advantage that it can be used on the consumers' works in machinery of well-understood type. The air motor is merely a simplified steam engine without boilers, and requiring less attention in working than a steam engine. There are also many subsidiary operations which could be carried on more easily by compressed air than in any other way. As to electricity, it would seem likely to prove a cheaper means of transmission than compressed air, and its adoption now in many factories, especially for lifting machinery, seems to show that ordinary workmen soon become capable of managing the new appliances required. The transmission of power to Buffalo is a problem of somewhat greater novelty and difficulty. The advantage of transmission to a town where manufactures already exist is obvious enough. Compressed air can, it appears, be taken to Buffalo without any excessive waste and at a cost which would leave to steam no chance of successful rivalry. It could be used for power purposes with the least amount of change in existing machinery in the factories. On the other hand, electricity seems specially adapted for a long-distance transmission. The Frankfort experiment shows that whether or not the best method of transmission electrically to such a distance is yet determined, yet such a transmission is perfectly practicable by methods which are known. The development of electrical power transmission has recently been so rapid that before the Buffalo transmission has to be undertaken, important improvements are likely to be effected.

The new industry of electric lighting has made it necessary to produce mechanical power for driving the dynamos in very large quantity, and new chemical and metallurgical processes are being discovered, which entirely depend for their commercial success on the provision of cheap motive power. The electric reducing processes by which aluminium is being obtained, electric depositing processes used in obtaining high-class copper, electric welding processes, and others must drift to places where cheap power in large quantity can be obtained. Niagara is likely to become not only a great manufacturing center, but the home of important industries of a new type.

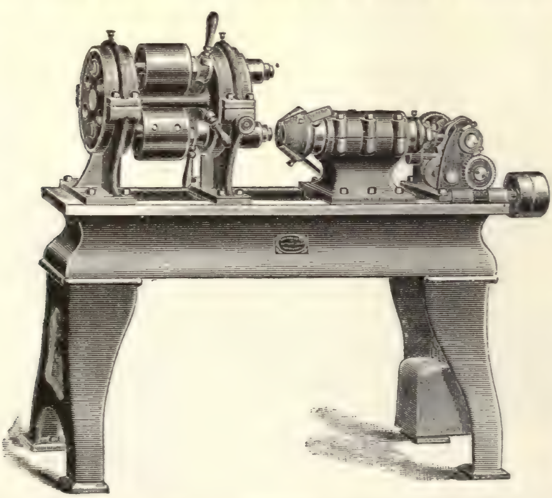


FIG. 1.—Nut-facing machine.

Nickel-in-slot Machine: see Vending Machine.

Nickel Steel: see Alloys and Armor.

Nozzles, Hose: see Fire Appliances.

NUT-FACING MACHINE. A machine for dressing the surfaces of nuts and bolts.

The Nicholson & Waterman

Nut-facing Machine, Fig. 1, has two duplicate spindles placed in a revolving drum, which is locked in such a position as always to have one spindle above the other. This arrangement permits the upper spindle to remain at rest, and allows the work to be removed and replaced, at the same time the cutters are facing the work on the lower spindle.

The cutters, which are made of bar steel ground to shape and tempered, are held in an oscillating head governed by a cam motion and change gears. Three cutters are used, shaped as in Fig. 2.

One cutter removes the first thread, the second relieves or rounds the corner, and the third finishes the flat. While each cutter can be shaped to do *all* these operations, this arrangement is much cheaper in time of grinding and resharpening. It will be seen that in this machine the cost to relieve the thread, chamfer, and face, is no greater than to face alone.

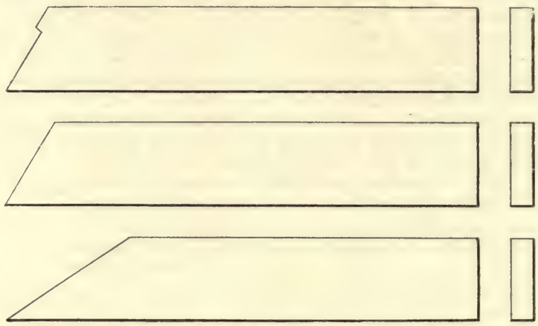


FIG. 2.—Nut-facing machine cutters.

Depending upon the size of the work, the machine should make from one to four oscillations per minute, each oscillation meaning a face dressed; and as this speed is independent of the motion of the spindle, and drives the operator, it can be relied on for estimates of product.

Newton's Nut-finishing Machines consist of a nut-facing machine, for facing the end of the nuts, and a nut-milling machine for finishing the sides. These tools are in use in many locomotive and nut and bolt works. The nut-facing machine, Fig. 3, may be used in place of a lathe or ordinary facing machine. The tools for facing can be made 12 in. long, and the

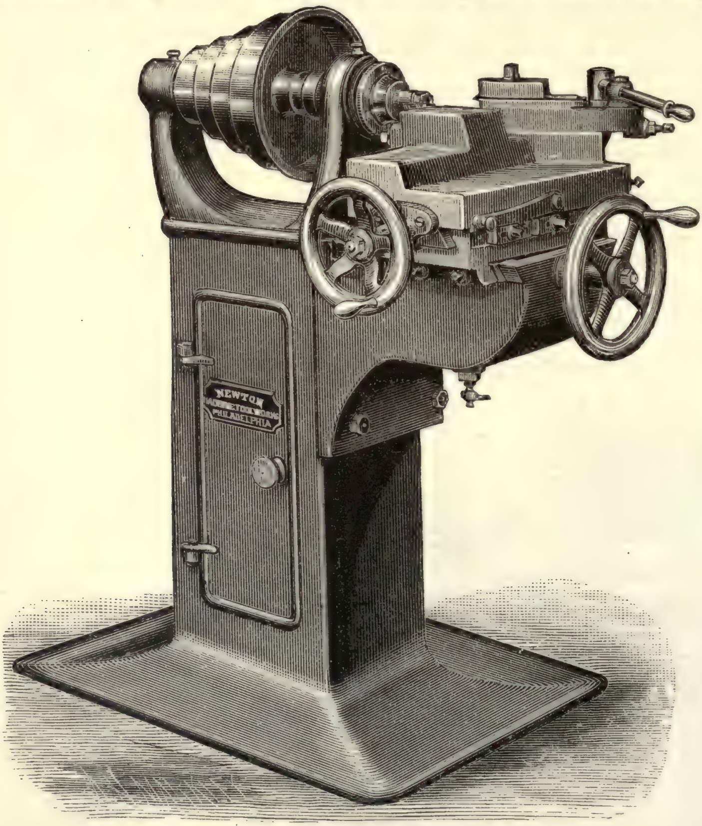


FIG. 3.—Nut-facing machine.

profiles desired are planed or milled lengthwise on their faces. An important feature of this tool is a device for reaming the burr from the thread. A small tool is held in the

carriage and operates on the nut the same time it is being faced; requiring only one operation to face the nut and ream the burr from the thread.

The double-headed nut-milling machine, Fig. 4, has two independent head stocks, each provided with an adjustable cutter, the teeth of which are made of $\frac{3}{8}$ in. square steel, and are

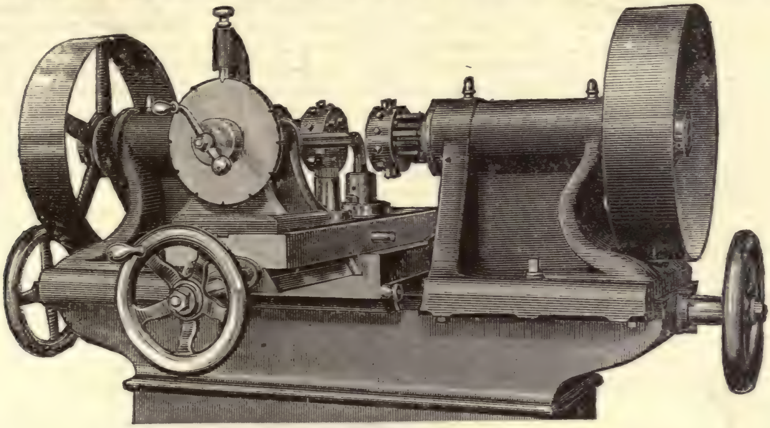


Fig. 4.—Double-headed nut-milling machine.

4 in. in length. The teeth are placed in two rows or circles in the cutter-head, and are held in position by set-screws. The first row acts as an advance or roughing cutter, and the inner row, which projects $\frac{1}{64}$ in. further, takes the finishing cut. There is a device provided for setting the nuts in position on the arbors, so that they will come exactly square with the face of the cutter when they are placed for milling, and no further setting is required. The machine mills two sides of from 12 to 20 nuts at once, depending on the thickness of the nuts.

NUT-TAPPING MACHINE. The machine here illustrated is designed to tap automatically square or hexagonal nuts. Immediately under the hopper, which is intended to receive the blank nuts, is an opening through which the blanks fall into a trough, which conveys them to the feeding mechanism. This part of the machine is so adjusted that the blanks are discharged with sufficient rapidity to supply the screw-threading mechanism, and at the same time to prevent more than the needed quantity being discharged. Provision is made for automatically stopping or starting the mechanism agitating the hopper, and thus starting or stopping the flow of blanks, whenever the number of blanks in the conduit is increased or diminished from the given quantity. The number of blanks in the conduit sufficient to stop or start the agitating mechanism may be varied as desired. The conduit is placed at such an angle that the blanks pass through it to the feeding mechanism by gravity, and it is made of such shape, that the blanks, as they fall in it and pass downward to the feeding mechanism, are gradually turned so as to fall on one of their flat sides. The lower portion of the trough is curved, as shown in the vertical sectional elevation, Fig. 2, to a vertical position, and joins the feed case at right angles. This feed case contains a T-shaped or three-way chamber, the main portion of which stands horizontally and at right angles to the end of the conduit. The cross portion of the T-shaped chamber stands vertical, and is pro-

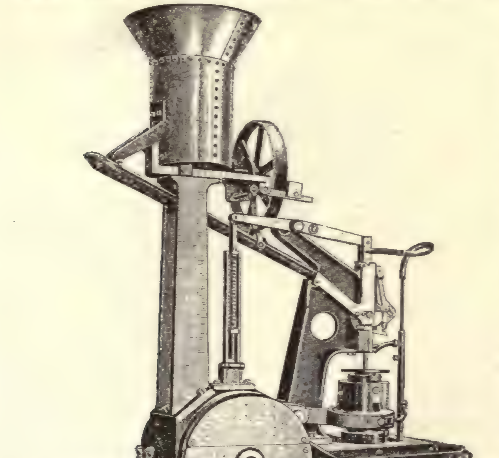


Fig. 1.—Automatic nut-tapping machine.

vided in its upper arm with a spring plunger of the size and shape of the blank to be tapped, the lower arm being formed in cross section to corespond with the blank to be tapped, and adapted to receive the upper end of the tap, *I*, supported at its lower end by the chuck, *C*. Immediately back of the point where the conduit joins the chamber is a plunger adapted to feed the nut forward. The actuating mechanism is operated by rod, *h*, the movement of which is controlled by the cam groove, D^2, placed on the wheel, *D*, which is operated through the worm on the shaft, *B*. The blanks from the conduit fall in a vertical position into the chamber. As the plunger advances, each blank is carried forward until the lower edge strikes against a projection formed on the bottom of the chamber. The blank is thus turned, and a further motion of the plunger carries it forward to a point immediately above the tap, *I*, and just below the spring plunger. Provision is made to insure that the blank will come to the proper place over the tap, and for holding it at the proper point to be fed under the tap by the spring plunger. At the proper time, the full force of the spring plunger is exerted against the blank, which is held upon the tap until it is formally engaged. The chuck, *C*, which carries the tap, is hollow throughout its length, and is secured in a beveled gear, B^2, the hub of which turns in a suitable bearing in the main frame. This gear is driven by another gear, as shown in Fig. 2.

The tap is supported in a vertical position, with the screw-threaded portion upward, the lower part or shank being of such a size as to permit the nut to drop off when released by the chuck mechanism. The tap is revolved by the chuck, and means are provided for auto-

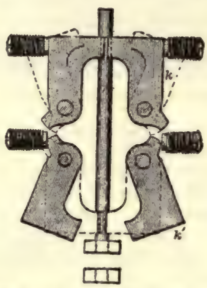


Fig. 4—Vertical section through chuck.

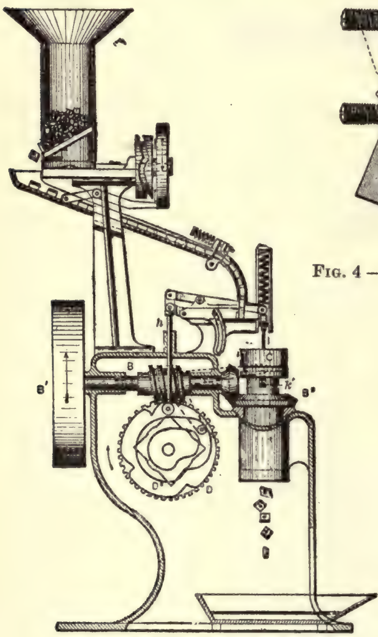


Fig. 2.—Vertical sectional elevation.

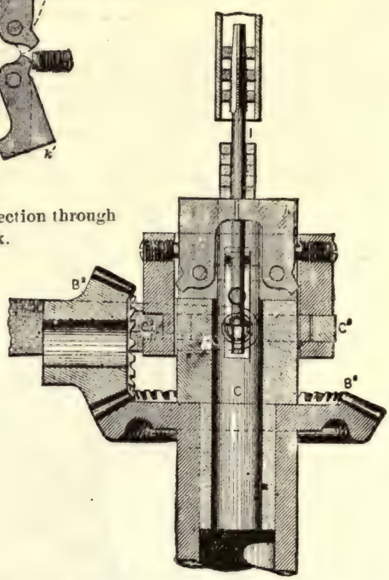


Fig. 3.—Section through chucks and operating mechanism.

Figs. 2-4.—Automatic nut-tapping machine.

matically disengaging the tap at one point when it is engaged at another, thereby permitting the finished nuts to drop by their weight from one end of the tap without any intermission in the motion of the machine, and without changing the longitudinal position of the tap. The main portion of the chuck, shown in vertical section in Fig. 3, consists of a sleeve provided at different points in its length with two pairs of jaws, which are adapted to embrace the tap at different points, and are placed preferably at right angles to each other, although they may be supported in the same vertical plane, as shown in Fig. 4. The jaws, *k k*, are each pivoted in a slotted opening in the sleeve, and are provided at the bottom with a cam projection. Surrounding the supporting sleeve is an outer collar provided in its periphery with a groove, and with adjustable projections provided to bear against the outer surfaces of the jaws. This collar is adapted to revolve with the sleeve, and is also capable of longitudinal movement on the sleeve. As it is moved longitudinally in either direction, its projections come against the cam projections on the respective jaws, causing them to separate, thus releasing the tap, the projections being so placed on the collar that when one pair of jaws is being opened, the other pair is closed tightly against the tap. Supposing the upper pair of jaws to be closed on the shank of the tap, for a time sufficient to tap a sufficient number of nuts, then the lower pair of jaws are closed on the shank, and the other pair

opened, thereby permitting the tapped nuts to fall on the shank, and to rest between the two pairs of jaws. The upper jaws then become clamped on the shank, and the lower jaws opened, when the finished nuts are permitted to fall freely.

Oil Cup : see Lubricators. **Oil Engine** : see Engines, Gas.

Opener : see Cotton-spinning Machines.

Open-hearth Furnace : see Steel, Manufacture of.

ORDNANCE. (See also ARMOR; GUN, PNEUMATIC; AND PROJECTILES.) PROGRESS ABROAD.—In June, 1879, a committee of ordnance was appointed in England for a full consideration of the relative advantages and disadvantages of muzzle loading and breech loading. The result was to commit the government to an experimental course of construction of breech-loading guns of some of the heaviest calibers then in existence. The committee was dissolved in 1881, after having fairly launched the country into gun-making upon the following principles: (1) A heavy steel tube, reinforced over the rear portion with wrought-iron coils and jacket, the trunnion piece being welded to the jacket; (2) the interrupted screw breech closure; (3) the Elswick cup obturator.

It was in the summer of 1879 that Krupp startled artillerists with the most magnificent series of experiments ever witnessed up to that time, the chief event being the trial of the new 40 cmt., 71-ton gun. This was a jacketed gun, made of crucible cast-steel, forged under the hammer, and weighed 71 tons; length of bore, 21·8 calibers. With a charge of 485 lbs. of prismatic black powder, and a 1,715-lb. projectile, a velocity of 1,702 foot-seconds was recorded with 20·9 tons pressure. The accuracy of the gun was remarkable; six shots were placed within a vertical rectangle measuring less than 18 in. in height by 71 in. in width. In 1881, Krupp made guns 35 calibers in length, Fig. 1, all of which had a jacket in which

FIG. 1.—Krupp gun.

was lodged the cylindro-prismatic wedge, the heavier calibers being hooked to the muzzle. The shot chamber (*b*), which was cylindrical, is now conical, and slopes into the bore gradually; the rifling has an increasing twist of from 50 to 25 calibers, instead of the former uniform twist of about 45 calibers.

Before the close of 1881 some 8-in. guns, entirely of steel, were under way in England, their form being a heavy steel tube supported by steel coils. Objections being raised to this method, there was another investigation into the subject of gun construction, which resulted in the following: (1) The breech screw should engage in the jacket; (2) the hoops should be carried well forward, and be made as long as was consistent with certainty of manufacture; (3) forged steel should be used; (4) steel to be open-hearthed, well tempered and annealed; (5) the De Bange obturator, shown by Fig. 4, should be used. The wire-wound system was found to possess certain important advantages, and designs for this type were ordered.

In those days the use of liners was quite general for the prevention of erosion, and a tube was used in continuation of the liner to the muzzle. As numerous guns have been put out of service through the splitting of the liners, the system as then adopted was not found entirely satisfactory. The locking of the joints was accomplished in this way: Take, for example, the locking joint between the jacket and the tube. The former is prepared at the forward end with a row of projections on its inner surface, and the tube is in like manner prepared with a row of projections on its outer surface. In the operation of shrinking on, the projections of one part pass between those on the other, and the jacket is then turned until they are in line, when the intervals are filled in by wedges driven under pressure. In the 16·25-in. gun longitudinal strength is provided by shoulders, and movement of the tube is prevented by shrinkage, assisted by a ring of yellow metal run into grooves near the front end of the jacket. This device is repeated near the front end of the thrust collar hoop.

In 1881–82, designs were prepared in France for guns of all service calibers from 65 mm. to 34 cmt. inclusive, in which the length of bore, save in a few guns intended for special purposes, is increased to 28 calibers. These guns constitute the 1881 model, and are the most approved pattern actually in service; they are hooped, but not tubed, and the material used throughout is steel, forged and oil tempered. The chamber is of much greater diameter than formerly, and the final twist of the rifling is increased from 4° to 7°. While all the parts unite to resist the transverse stresses, the longitudinal stress is borne by the tube alone. Certain difficulties having developed with large guns built after the 1881 model, notably in obtaining an equable temper in the large masses of steel called for by the design, a new design was proposed for the 27 cmt. and superior calibers. These guns are tubed, a sleeve screws onto the rear of the tube for the breech plug; the tube is hooked to within about 8 calibers of the muzzle; a jacket about 16 calibers long is shrunk over the first layer, and is in turn reinforced with a second layer of five hoops, one of which carries the trunnions.

The heaviest guns in existence are the four Krupp 119-ton guns, of 15·75 in. caliber, made for the Italian government and designed in 1882. The terms of the contract required that one gun of the four should fire at least fifty rounds with projectiles of 2,028 lbs. weight, to which should be given a muzzle velocity of 1,804 foot-seconds. Ten of the fifty

rounds were to be fired at a target 2,734 yards distant, and it was stipulated that all of the shot should fall within an area 10 66 ft. square. The firing was continued up to eighty-two rounds, the pressure rising to 18·9 tons, with a velocity of 1,876 foot-seconds.

The above construction of ordnance is practically what obtains to-day in foreign gun shops. The question of larger calibers has been brought up and decided against. The 111-ton English guns were made by contract for home consumption and there were grave faults of design developed in the trials which the makers are now trying to remedy by partial reconstruction. As to the question of necessity, the 16-in. gun is required to give

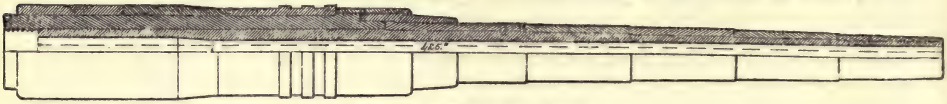


FIG. 2.—Built up forged gun.

at battle ranges, and occasionally at long ranges, the penetrative power and destructive effect which is lacking in the 12 and 13-in. calibers. The striking energy of the 16-in. gun is about 2·4 times that of the 12 in., and its penetration at five miles is equal to the 12-in. at one mile. British vessels carry 34 guns, French 54, Italian 40, none of which are less than 13·4 in. A naval estimate of the highest power guns required cannot, however, be accepted as a standard, as the land defenses should avail themselves of their advantages over ship carrying capacity, and maintain at all times their natural superiority over naval armament. The ships are limited for space, and especially by weight—objections which in themselves are minor matters in shore defenses.

PROGRESS IN THE UNITED STATES.—In 1884 the main batteries of United States war vessels were composed of (1) Dahlgren smooth-bores, chiefly of 9-in. caliber ; (2) muzzle-loading guns of the Parrott type ; (3) 8-in. muzzle-loading rifles converted on the Palliser system from 11-in. smooth bore, and (4) 60 and 80 pounder breech-loading rifles, resulting from the conversion of Parrott muzzle-loading guns. In the army there was placed in service 210 8-in. rifles, converted from 10-in. smooth-bores, having three times the accuracy and more than double the power of the latter, and should war arise to-morrow they are the only reliable rifles that we have available for coast-defense. These guns of the same general construction, with Krupp mechanism, unchambered, and firing a charge of 35 lbs. of powder, were a practical success. The 3-in. wrought-iron muzzle-loading rifle was cut off near the bottom of the bore, and screwed in from the rear was a steel breech receiver, through which the bore is prolonged. The breech-block, supported in the breech receiver, was of the Krupp pattern, made in this country ; the Broadwell ring was used.

The result of the appointment of various committees, who investigated gun-making possibilities at home and abroad, was the conclusion that the solution of the gun question lies in the manufacture of the built-up forged-steel gun, Fig. 2, and that the industry of making forged steel for such guns should be established in this country. The conclusions of the various committees and boards have thus far been very useful in helping the navy build guns in the quantities needed for the new vessels, and this beneficial policy will probably soon be extended to the land service. The whole number of sets of forgings procured, or under contract, for the navy are 148, ranging from 3 to 12 in. in caliber, to which must be added eight 8-in. and three 10-inch rifles for which the forgings were procured from England.

MANUFACTURE OF ORDNANCE IN THE UNITED STATES.—The first built-up forged-steel gun made in this country was a 6-in. breech-loading rifle. The tube was annealed metal, but the jacket was of oil-tempered steel, imported. The two guns following were also 6-in., of annealed metal, the forgings being of domestic manufacture, as all have since been, with the exception of those above mentioned. Notwithstanding the considerable delays made by waiting for the first deliveries of the forgings, and the lack of machinery and plant for the new and superior quality of work demanded, guns and their carriages are now being turned out as fast as the new vessels are ready for them. Finished guns have been subjected to the proof required by law, which constitutes a series of 10 rounds fired with all possible dispatch. All guns have thus far stood the firing tests perfectly and have given satisfaction in service. The 6-in. guns, as mounted in broadside aboard the men-of-war, are shown in Fig. 3. The carriage is known as a gravity return ; the gun after being fired runs down the slide (*a*) on the carriage trucks (*b b b b*) ; the training is done at (*c*) by the cogs, and the elevating at (*d*).

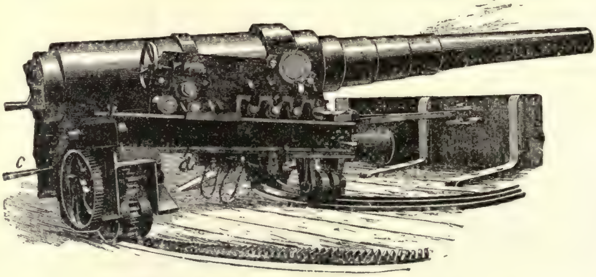


FIG. 3.—6-inch breech-loading rifle.

In their main features the army and navy guns are alike, the most important difference in construction being that, in the navy guns, the trunnion hoops are made of oil-tempered and annealed castings, and are screwed on cold, while in the army these hoops are forged and assembled by shrinkage. In the matter of charges, also, the practice differs, in that the rule in the navy is to use a charge of powder equal to about one-half the weight of the shot, whilst in the army the weight of projectile is made proportionately much heavier. The lighter projectile gives a high velocity with a relatively flat trajectory, which is best adapted to the conditions of naval combat. There is certainly no mechanical difficulty in making these guns which cannot be overcome. The machinery of the finished surfaces requires less care than is exercised in making paper rolls. A variation of 0·003 of an inch is usually allowed in turning the shrinkage surfaces for a gun, and the shrinkages required to produce the maximum resistance of a gun built up of several layers, may be obtained by a relatively heavy shrinkage on the first layer, and a relatively light shrinkage for the second layer, and so on, or the reverse.

The division of the gun into many parts has all the advantage of procuring the very best of material, because of the thorough working which each part receives, and the facility for examination of the quality of the material which is afforded. In the construction of these guns, the different parts are assembled to give great economy of material. The jacket affords all the requisite longitudinal strength. The methods pursued in the manufacture and application in the gun structure, essentially fit them to afford the kind of resistance required. The tube in a built-up gun is subjected to the greatest strains in the structure, and there is always left a margin of elastic strength in the outside parts, which, should the tube be heated to excess, would be equivalent to a case of a gun assembled with a greater shrinkage. So that in firing, the place of most dangerous strain in the gun—that is, at the surface of the bore of the tube—would be under a less, instead of a greater, strain.

Breech Mechanism.—The system of breech mechanism in use is that of the slotted screw, which is the type in use in France, Italy, and England ; the De Bange gas check, with mushroom head and plastic obturator, has also been quite generally adopted with heavier calibers in this country. The details of this mechanism vary in different countries, only the main features being preserved. Gas-check rings replace the plastic check in Italian and in the Armstrong guns, and they differ in details from each other, and from the De Bange mechanism. The different parts will be readily understood from the illustration, (Fig. 4): mushroom head, slotted screw, breech plug, catch, sight bar, and handle. The Krupp mechanism has been adopted by Russia and Germany. In regard to these two systems, so thoroughly tested and proved, it may be remarked that the slotted screw has been generally received by gunmakers with more favor than the Krupp, and probably the principal reason for this is that the latter requires a forging of larger diameter for the block-carrying cylinder than the former, which may even be attached in the tube forging itself.

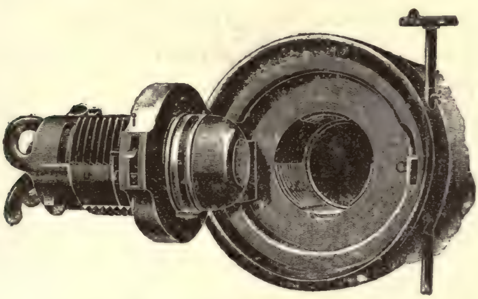


Fig. 4.—Breech mechanism.

Tests of Ordnance.—Three of the systems contemplated in 1883—the built-up steel, the simple cast-iron, and the multi-charge—have been subjected to trial ; another, the combined cast-iron and steel, has been submitted to partial trial only, in the proof of a 12-in. muzzle-loading rifled mortar hooped with steel, whilst the rifles made on the same system, and the wire-wound guns, are in a more or less forward state of completion. The principal feature of the multi-charge gun consists in the accelerating principle as applied to the action of the powder upon the projectile, which is sought to be obtained by using a series of powder charges placed in pockets at intervals along the bore near the breech, which are intended to be ignited by the inflamed gases of the breech charge following the passage of the projectile over the opening of each pocket in the bore. The breech charge is relatively light, to give a gradual impetus to the projectile, which is placed immediately in front of it, and in rear of all the pockets. Higher energy and greater penetration than this gun has been able to show are matters of every-day record with guns using a single charge of powder, and with a much safer pressure on the gun.

A 12-in. breech-loading rifle, made of cast-iron, was built, and tried at Sandy Hook, N. J., in 1886. The gun had the exterior curved outline of the Rodman model, with the thickness of the wall decreasing toward the muzzle, and proportioned to the powder pressure to be withstood in the different sections of the bore. Except the sleeve that holds the breech block and the breech mechanism, the gun was wholly of cast-iron, and in one piece. The erosion of the bore during the trials became so great that gauging was very difficult, flared openings having a depth of 0·15 of an inch being made.

The first experimental rifled mortar, 12-in. muzzle-loading, was completed in 1884. The reasons leading to the adoption of the muzzle-loader for the first experimental type were because it was then thought that the old method of loading from the muzzle would be, on the whole, better adapted to such short pieces, as combining simplicity and cheapness, together

with less care and attention required in service, as compared with the breech-loader. The piece has been fired over 400 times, and is considered amply strong for service. Its best record for accuracy is a target of ten shots; range, 3,490 yards; 26 lbs. of powder, 610-lb. projectile ; percentage, 99 hits for 100 shots on the deck of a vessel 330 ft. long, and 60 ft. wide.

12-in. breech-loading rifled mortars were, however, thought to be more desirable, as further experiment developed an unsatisfactory degree of accuracy, and a lack of uniform steadiness in the flight of the shell. In general design these mortars show a short rifled piece of about nine calibers length of bore, weighing about $14\frac{1}{4}$ tons, having the slotted screw-block and breech mechanism, and embodying a new and special design of retracting gear. The body is cast-iron, having two rows of steel hoops shrunk on, extending from the breech over about two-thirds the length of the piece. The trunnions are forged as part of one of the steel hoops.

The Navy Department has in hand a 6-in. steel tube wire-wrapped gun, partly completed. The army is wrapping a 10-in. breech-loading cast-iron rifle. The muzzle half of the cast-iron body is not covered. A steel trunnion band is shrunk on the outside of the wire, and the portion of wire in front of the band is covered by a steel sleeve, also shrunk on, which will transmit the thrust of the trunnion band to another steel hoop shrunk on the cast-iron body, and backed up by a key ring shrunk on cold. The 10-in. carries longitudinal bars, and is wound from breech to muzzle. The tube is of steel, and extends entirely through the gun. The longitudinal bars or staves form a cylinder, fitting the tube over about one-half its length from the breech, and connected indirectly with the trunnion band and the breech block.

Two steel cast 6 in. guns were built, one of Bessemer steel, and the other of open-hearth steel. The former burst at the second round, and the latter had a permanent extension of the bore, and other defects were developed that caused the rejection of the gun. The steel breech-loading guns are as follows :

Table of United States Ordnance.

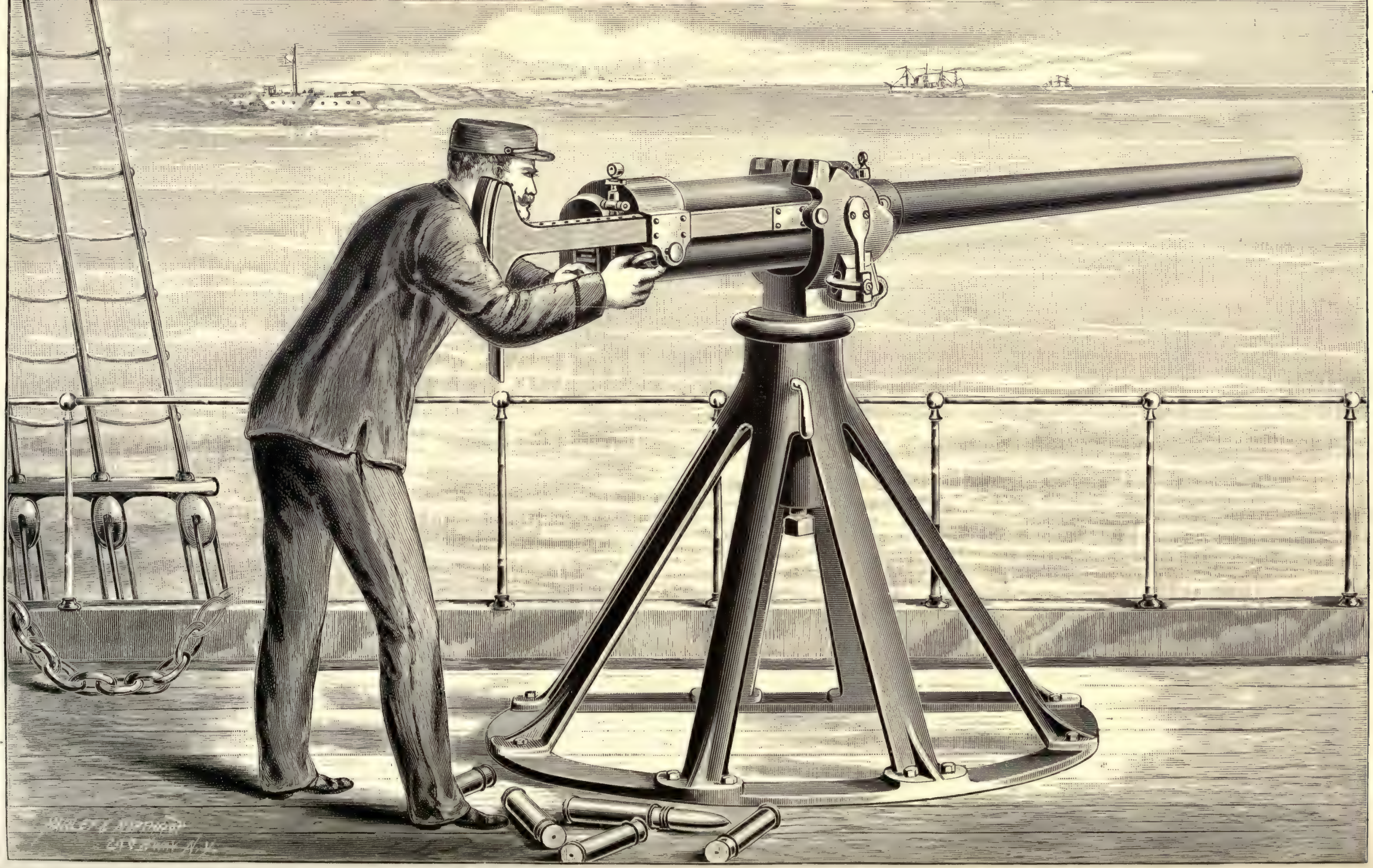
NAVY.

Calibers.	Weight. Tons.	Total length. Feet.	Length of bore. Calibers.	Charge.		Powder pressure. Tons.	Initial velocity. Feet.	Muzzle energy. Ft. tons.
				Powder. lbs.	Projectiles lbs			
4-in. R. F. and B. L. R. Mark I..	1·5	13·7	40	14	33		2,000	915
5-in. R. F.	3 1	17·4	40	30	50		2,250	1,754
5-in. Mark I	2·8	13·5	30	30	60		2,000	1,664
6-in. Mark I., II., III	4·8 4·9	15·8 16 3	30	47 50	100		2,000	2,774
6-in. (35 calibers.)	5 2	18·8	35	47	100		2,080	3,000
6-in. (40 ")	6 0	21·3	40	47	100	15	2,150	3,204
8-in. Mark I. and II	12·3 13·0	21·5	30	115	250		2,000	6,934
8-in. Mark III	13·1	25·4	35	115	250		2,080	7,498
10-in. Marks I. and II. (30 calibers.)	25·1 25 7	27·4	30	240	500		2,000	13,870
10-in. Marks I. and II. (35 ")	27·1 28·2	30·5 31·2	35	240	500		2,080 2,100	15,000 15,285
12-in	45·2	36·8	35	425	850		2,100	25,985
13-in	60 5	40·0	35	550	1,100		2,100	32,862

R. F., rapid fire. B. L. R., breech-loading rifle.

ARMY.

Calibers.	Weight lbs.	Total length. Feet.	Length of bore. Calibers.	Charge.		Powder pressure. Tons.	Initial velocity. Feet.	Muzzle energy Ft. tons
				Powder. lbs.	Projectiles. lbs.			
MOUNTAIN AND FIELD ARTILLERY.								
3-in. mountain gun	218	3·9	14·	0·88	12·	6·5	870	63
3·2-in. light field gun	829	7·56	26·	3·75	13·5	15·	1,675	263
3·6-in. " " "	1,181	7·56	23·	4·50	20·	16·	1,554	335
3·6-in. field mortar	244	2·75	5·25	1·00	20·	8·	650	58
SIEGE ARTILLERY.								
5-in. guns	3,660	12·15	27·	12·50	45·	16·	1,830	1,000
7-in. howitzer	3,710	8·06	12·	9·75	105·	12·5	1,085	857
SEA-COAST ARTILLERY.	Tons.							
8-in. gun	14·5	23·21	32	130	300	16·5	1,935	7,787
10-in. "	30·0	30·60	34	256	575	16·5	1,940	15,000
12-in. "	52·0	36·66	34	440	1,000	16·5	1,940	26,000
12-in. mortar	13·00	11·76	10	100	800	16·	1,150	7,324
12-in. " cast-iron, steel hooped.	15·25	10·75	9	80	630	12·5	1,152	5,796



THE DRIGGS-SCHROEDER QUICK-FIRE GUN.

Quick-fire Guns.—The Hotchkiss revolving cannon and the torpedo boat came into prominence about the same time, and for a while the gun was the more powerful, but as the boats were gradually perfected, heavier guns were demanded, and the 1-pounder grew to a 2-pounder and then to a 4-pounder. These guns were found too heavy for their energy and killing power, and the French government suggested a single-barreled gun that was to use metallic ammunition. Mr. Hotchkiss undertook the contract, altered his breech-block so that it would slide vertically, used a very long barrel, and introduced in a 3-pounder the first gun, of its type. England, in 1881, demanded a 6-pounder, and Hotchkiss and Nordenfeldt produced guns that to-day form part of the armament of nearly every great naval power, Germany being the most important exception. In 1883 the United States gave an order for rapid-fire guns which was the first regular order given by any government.

The Hotchkiss is the wedge system of mechanism, and has a falling or vertically moving block, which is as applicable to the 5 and 6-in. calibers as to the 3-pounders, the same design being used of rall, every part being exactly the same pattern, larger or smaller as the caliber requires. The breech-block is worked by a lever arm which travels in a slot, so that the first movement of opening gives but a small descent to the block. This motion becomes quicker, until the block falls freely and throws its full weight in aid of the extraction. The extractors have a straight, positive motion with a long travel, and are actuated by a groove in the breech-block, having a slow motion at first, but exerting powerful leverage as the block is opened wider. The block is supported when open by the head of a stop screw passing through the side of the breech.

The firing mechanism consists of an ordinary pivoted hammer with main and sear springs. Cocking takes place automatically by heel-and-toe cams outside the right part of the breech, but it can be done with the fingers, and the entire breech mechanism can be removed, whether the block be closed or opened. Except the 1-pounder and the mountain gun, all of this system are jacketed to stand a pressure of 18 tons. The projectiles have a

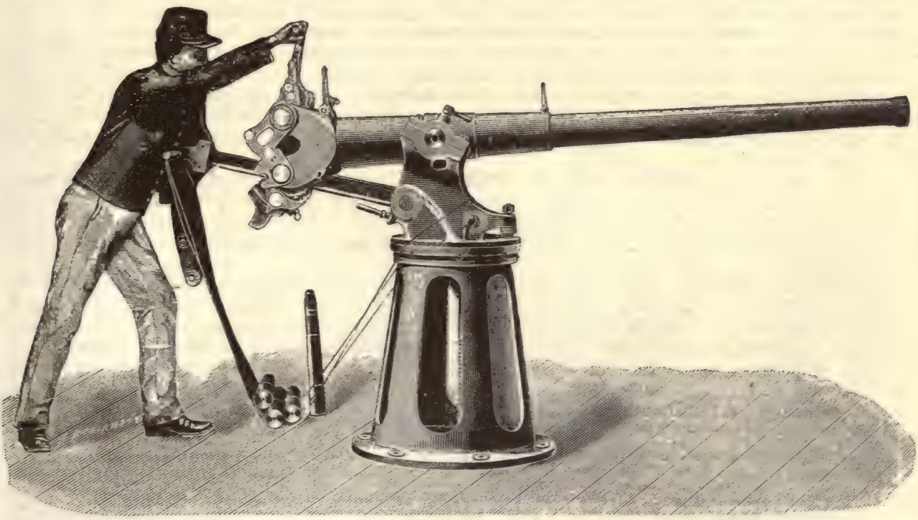


FIG. 5.—Engström rapid fire gun.

travel of 35 calibers, which makes the gun about 44 calibers long. All guns above 1-pounders must exceed 2,000 ft. initial velocity, with black or brown powders ; 2,350 ft. being reached with smokeless powder.

Recognizing the great advantage of the rapid-fire system, and anticipating the large field of employment for a reliable and effective weapon of this kind, Lieutenants Driggs and Schroeder, U. S. N., took hold of the subject in 1887, and by careful study and experiment developed a weapon that has already met with favor among naval experts. The jacket is in two parts, one of which is termed a sleeve and is shrunk upon the tube, the two parts being connected under the trunnion band by the screw thread of the latter. The breech mechanism is in rear of the jacket, which forms its natural housing and protection. One of the most important features in the breech closure is the lightness of the block, which is further enhanced by revolving the block upon an interior axle. There are two independent extractors, either one of which will eject the empty cases.

The breech being closed and the gun fired, the operator revolves the handle through 90°, which opens the breech, full-cocks the firing mechanism, and throws the empty cases well to the rear. The breech being closed, the block is supported by a cam which fits in a recess in the center of the block. Moving the handle around revolves the cam, forcing the firing pin to the rear and cocking it. The twist in the rifling is 1 turn in 30 calibers in the 1-pounder ;

in the 3-pounder 1 turn in 100 to 1 in 25 calibers ; and in the 6-pounder 1 turn in 150 to 1 in 27 calibers. In tests for rapidity, the 6-pounder was fired eight rounds in 20 seconds. In testing for accuracy, all of 20 shots fell inside a lateral distance of six feet in 1.500 yards.

The Nordenfeldt rapid-fire guns were very similar in appearance to the Hotchkiss, and differed but in few particulars. The breech-wedge of the Hotchkiss was in one piece, while that of the Nordenfeldt was in two. The former was capable of almost instantaneous pointing by means of a shoulder-piece, while the latter was pointed a little more slowly by means of screw gearing manipulated by two hand wheels. The former was mounted on a non-recoil elastic frame stand, and the latter was mounted for short recoil. Since these pioneers, others have entered the field, the principal among them being Armstrong, Krupp, Gruson, Maxim, Thronson, Engström (Fig. 5), Canet, Daudeteau, and Skoda. In general terms, the principal differences in these types are those pertaining to details of breech mechanism. The form of breech closure in each is either that of a sliding wedge or of an interrupted screw, and, in all, the longitudinal strains are taken by the jacket instead of by the tube.

The ingenuity displayed in the Maxim automatic gun is so remarkable that it deserves rather more than general notice, although it may be outlived by a number of the other types. The gun is single-barreled, so arranged in its mountings as to slide freely to and fro in its supports when firing. The first round is fired by hand, and the automatic system is set in motion by the resultant recoil as follows : The recoil opens the breech, withdraws a loaded cartridge from the belt, extracts the empty case, and cocks the hammer, at the same time stretching a spiral spring, which, when the recoil is absorbed, forces the barrel into the firing position ; the return of the moving parts expels the empty case, thrusts a loaded cartridge into the barrel, pushes a fresh cartridge in the belt into position, closes the breech, and pulls the trigger.

Almost at the beginning of the recoil, a shaft and crank begin to rotate, and thus gradually draw all other movable parts away from the barrel. A sliding piece, which has an undercut groove on its forward face, exactly fitting the head of a cartridge, serves the double purpose of breech closure and carrier for transferring cartridges from belt to gun ; as it moves away from the barrel it withdraws an empty case from the bore and a loaded cartridge from the belt, and as its rearward motion continues, it drops, partly by gravity, and partly by the action of a spring, into such a position as to bring the loaded cartridge into line with the barrel, and the empty case in line with the discharge tube. In tests for durability, an average rapidity of 600 rounds per minute was obtained, the loading and firing mechanism working faultlessly.

In a test for rapidity made by the Ordnance Department, U. S. A., 2.004 rounds were fired in 1 min. 45 sec. In a subsequent test for accuracy, out of 334 shots fired at a distance of 300 yds. at a target 12×26 ft., 268 hits were made. The cartridges used in the two last-named tests were solid head, containing 70 grains of powder and a bullet weighing 405 grains.

As the benefits to be gained from the accuracy, rapidity, and power of rapid-fire guns became evident from practical tests of the 3 and 6 pounders, it was seen that their sphere of utility admitted of extension, and large calibers of greater power were constructed from time to time, until the present limit of 6-in. caliber has been reached. But before any of these larger guns were ready for use, special recoil-checking arrangements, with an automatic firing position, were introduced, by means of which the loss of time from running out and relaying the gun after firing was reduced to a minimum. What limits the further extension of the system to still larger calibers is not the recoil, but the fixed ammunition. The combined weight of cartridge-case, charge, and projectile should be such that one man could handle it with ease and rapidity, and could readily exert sufficient power to extract the empty cases after firing.

The successful use of guns of this type up to a caliber of 6 in. necessitates efforts to obtain greater rapidity of fire from high-power guns, and much quicker means of supplying ammunition. The next step in their development, as already pointed out by ordnance experts, lies in changing the tube, decreasing the size of the powder-chamber, and strengthening the walls of the case, all made necessary by the introduction of smokeless powders, which, with smaller charges than of present service-powders, give the same chamber pressures, but higher pressures all along the bore.

In order to cope successfully with swiftly moving torpedo-boats, a gun must be capable of giving, for a short period of time, a rapid and continuous fire of explosive projectiles, having great penetrative power up to a range of 2,000 yards, and of such quick and accurate training as to admit of being kept constantly bearing on the torpedo-boat. It was these demands that introduced the rapid-fire artillery, but the machine guns of Gatling and Nordenfeldt, the Gardner gun, and one or two others, are still retained in service, and are considered as useful auxiliaries where there are exposed bodies of men or protection of light scantling. In these weapons the last few years have seen but slight changes, and what has been done was in the line of a positive feed, a reduction of weight, and in the fittings, rather than in any marked alteration in their mechanism. Full descriptions of all modern ordnance will be found in the files of *Engineering* (London) for 1890, 1891, and 1892. See also Reports of Chief of Ordnance, U. S. A.

Ore Cooler: See Mills, Silver. **Ore Drier**: see Mills, Silver. **Ore Roaster**: see Furnaces, Roasting. **Ore Smelting**: see Furnaces, Smelting. **Ore Washer**: see Ore-dressing Machinery.

ORE-CRUSHING MACHINES. Machines for crushing ore or rock may be divided into two classes, coarse-crushing and fine-crushing. The ore as received from the mine is usually in large pieces, requiring a preliminary breaking, which is accomplished by machines of the first class, before the succeeding and final crushing, which is done by machines of the second class. The coarse-crushing machines in general use are nearly all of the jaw type, most of them being modifications of the well-known Blake rock-breaker. Fine-crushing machines are of two kinds, those in which the rock is broken by direct pressure, or impact, as in the case of stamps, rolls, and Chilian mills, and those in which the comminution is effected by a grinding motion. The selection of any particular machine depends upon the purpose for which the rock or ore is to be ground. It is obvious that in pulverizing to any given size, a greater proportion of fine material will be made by the machines which have a grinding action, in which the distance to which die and shoe approach each other, as in the case of rolls and multiple-jaw crushers, can be regulated, than by those which act by a direct blow. In some work, such as crushing ore for mechanical dressing by water, it is desirable to make as small a proportion of slimes as possible ; hence rolls are commonly used. In crushing ore for gold and silver milling, where it is necessary that the whole shall be crushed fine, and the proportion of slimes is not of so much consequence, stamps are used. For excessively fine grinding, as is desirable in pulverizing phosphate rock for the manufacture of superphosphate, for comminuting ochre, etc., for mineral paint, and work of like kind, the grinding machines are well adapted and are generally employed.

COARSE-CRUSHING MACHINES.—*Blake's Challenge Crusher* is an improved form of the well-known rock-breaker, which, by many years' experience, has been proved to be the best type of coarse-crushing machine in use. It is constructed upon the old Blake principle—eccentric, pitman, and toggles—but the pitman is made of somewhat different form, admitting of largely increased length of toggles without adding materially to the weight of the machine, and consequently reducing strains on the pitman and shaft. The machine is so cushioned that if, as sometimes happens, a piece of steel—a sledge-hammer, for example—should accidentally fall between the jaws, it permits a partial revolution of the fly-wheels before coming to a full stop, thus doing away with the rigidity inseparable from machines with cast-iron frames, and greatly diminishing the chances of breakage. In this machine all tensile strains are upon wrought-iron or steel, the principal strain being carried by longitudinal tension-rods.

The Krom Crusher (Fig. 1) is a modification of the Blake. The motion of the movable jaw is imparted in the usual manner, by eccentric, pitman, and toggles. The machine is strengthened by longitudinal tie-bolts, through the frame, which receive all the strain due to crushing the rock or ore. In the toggle abutment, through which the main tie-bolts pass, are recesses around the bolt holes, which are covered with wrought-iron washers of such strength that they will not bend under the ordinary strain in crushing the ore, but will yield to excessive strain. The movable jaw is pivoted at its lower end instead of at the top, as in the Blake crusher, this method of hanging the jaw giving a product of more uniform size, and giving the least motion at the point of greatest strain. The die and shoe, or the crushing faces of the jaws, are smooth, being made of bars of good steel, of proper size, laid horizontally. Thin strips of metal are provided to put behind the bars to keep the wearing faces in line. The toggles are made with rolling ends with the object of reducing friction. The ends are made with three teeth, which mesh with the toggle-seats, the toggles being thus held in place.

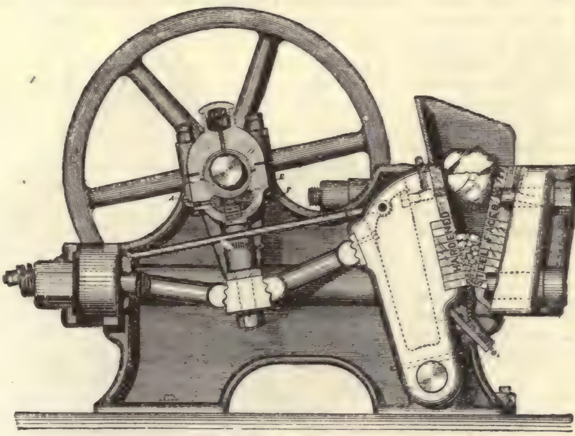


FIG. 1.—Krom crusher.

The Fulton Crusher is constructed upon the same principle as the Blake, with modifications which it is claimed render the wearing parts more accessible and more easily renewed. The stationary jaw is held in place by flat iron bars, having eyes forged on their ends, slipping over shafts in the top and bottom of the jaw. By taking out pins in the ends of the upper shaft, and loosening the nuts holding the upper flat iron bars at the back of the rock-breaker, the latter can be slipped off the upper jaw-shaft, and the jaw, pivoting on the lower shaft, can be opened and lowered, making it easy to replace the shoe, die, and cheek-plates. A spring is placed beneath the loose babbitt-lined gib, bearing against the lower part of the eccentric of the pitman-shaft, taking up lost motion and preventing heating and pounding. The tension of the spring is regulated by a wedge, placed beneath it, and adjusted by means of nuts on the outside of the pitman. The shoes and dies are composed of alternate layers of wrought-iron and hardened machine-steel bars placed horizontally on

edge, and held together by a heavy wrought-iron band shrunk around them. The iron being softer than the steel, wears away more rapidly, causing the shoe and die in a short time to present a corrugated surface to the rock, and giving a better crushing effect. The surfaces of the iron bars wear but a short distance below those of the steel, being protected by the latter. The crushing of the rock upsets the iron bars and thus tends to force them more firmly within the band.

The Buchanan Crusher (Fig. 2) is constructed upon the same principle as the Blake. The essential point of difference is in the method of supporting the movable jaw, *B*. In the Blake this swings on a shaft passing through its top; in the Buchanan the jaw, which has a long, horizontal projection under the pitman, *C*, is supported by two rocking arms, *F*, pivoted at their lower ends upon the base of the breaker. Consequently, every part of the jaw moves evenly back and forth. There is no other strain on the rocking arms than the weight of the jaw, which the makers claim is an advantage, as there is no direct strain due to crushing imposed on pivotal pins or shafts, as in other breakers of this type.

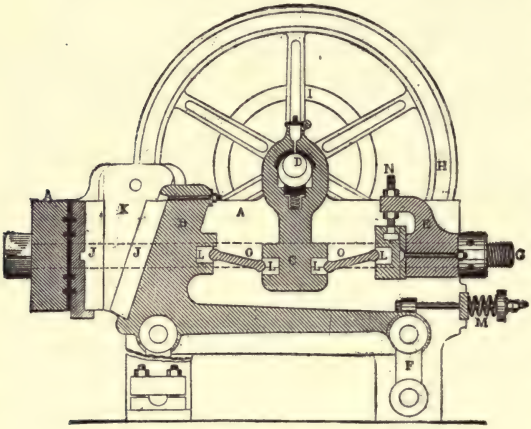


Fig. 2.—Buchanan crusher.

The Brennan Crusher (Fig. 3), which is much used for breaking rock for macadam, is a modification of the Blake crusher, differing mainly in the fact that the driving-shaft is placed near the base of the frame instead of at the top. The pitman and toggles, consequently, work above the eccentric instead of below it. In the base of the machine is an oil-chamber, *O*—the oil being kept at uniform height by means of supply and overflow pipes—in which the eccentric works, thus insuring a constant and ample lubrication of this important wearing part. The oscillating jaw, *D*, is pivoted at the top as in the Blake crusher, but is much shorter. The crushing-plate, *C*, of this jaw is correspondingly longer, and is hinged in the jaw at its upper end. On the frame of the machine, just behind the lower end of the hinged plate, is an adjustable cam, *F*, by which the stroke of the plate can be cut off to any desired proportion of the stroke of the oscillating jaw, the lower end of the plate resting against the cam during the time the stroke is cut off. The impact of the plate against this cam facilitates, it is claimed, the discharge of the crushed material. By this arrangement of the jaw proper and the plate, it is obviously possible to give approximately the same length of stroke throughout, which is an impossibility in any machine in which the jaw is pivoted at one end only.

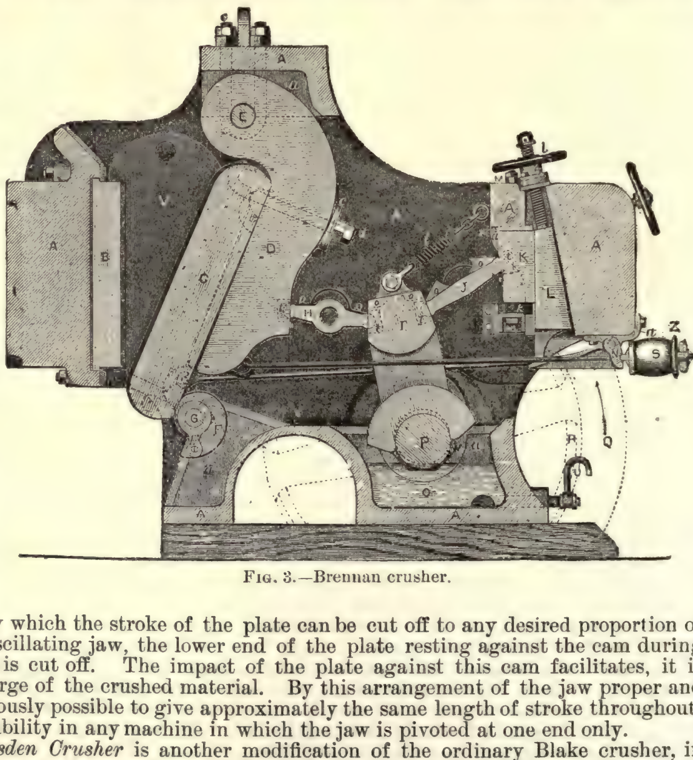


Fig. 3.—Brennan crusher.

The Blake-Marsden Crusher is another modification of the ordinary Blake crusher, in which the eccentric-shaft is placed at the extreme rear end of the machine, the motion of the pitman being transmitted to the toggles, and thence to the oscillating jaw through a bent lever. The fulcrum of the bent lever is a horizontal shaft through the center of the machine.

The toggles are seated in the short arm of the lever which extends upward; the long arm projects backward, and is pivoted at its end with the lower end of the pitman. The oscillating jaw is pivoted at the top, as in the ordinary Blake crusher. It is claimed that greater power is gained by the pitman and lever construction of this machine, which is extensively used in England, but rarely, if at all, in this country.

The Nichols Crusher is a machine of the jaw type in which the fixed jaw of other machines of this class is replaced by a heavy cast-iron cylinder, supported upon a horizontal axis. The oscillating jaw is mounted on a revolving eccentric shaft, and works against the

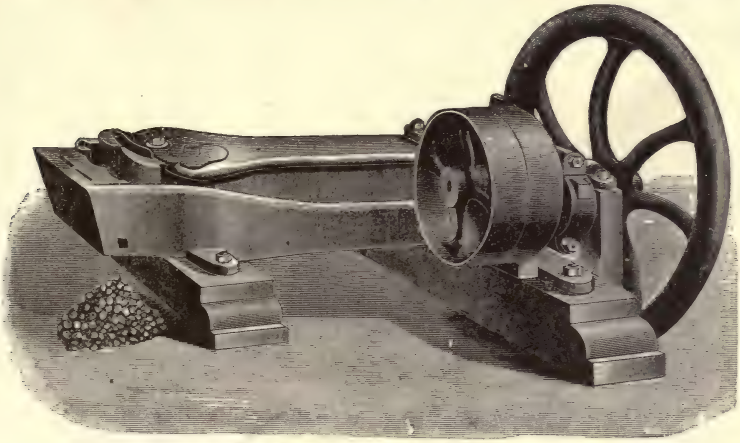


Fig. 4.—Forster crusher.

cylinder in a rotary oscillating motion, which causes the cylinder to move slowly around with each descending stroke of the jaw. The cylinder is prevented from moving back, as the jaw ascends, by small balls, which are placed in each end of the cylinder and against a wedge-formed projection on the inner face of the sides of the jaw, forming, in effect, a ratchet. The lower end of the oscillating jaw is secured to the shaft of the cylinder by flat connecting bars. In the ends of these bars are heavy set-screws, bearing against the cylinder-shaft, by which the distance between the lower end of the jaw and the cylinder is adjusted for either coarse-crushing, reducing, or pulverizing, packing-blocks being placed against the opposite side of the cylinder-shaft. The oscillating jaw is provided with a shoe of either

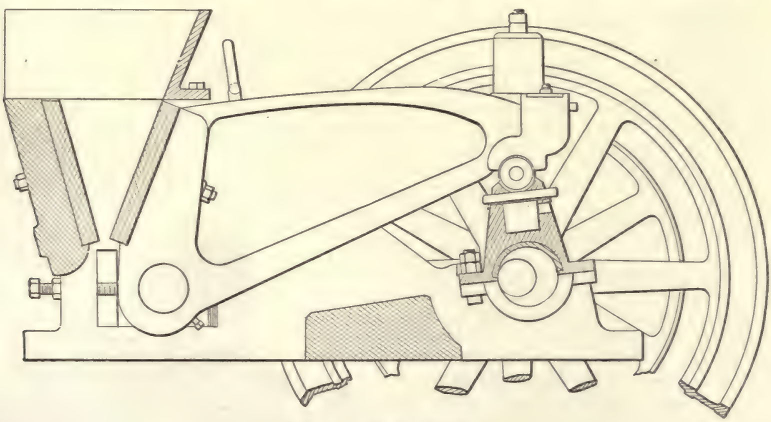


Fig. 5.—Dodge crusher.

white-iron or steel, which can be reversed from center to side, or end for end, when worn. The eccentric shaft is fitted with two heavy balance-wheels and tight and loose pulleys.

The Forster Crusher (Fig. 4) is a coarse-crushing machine of the jaw type. The oscillating jaw is pivoted vertically, however, instead of horizontally, as in most machines of this class. The oscillating jaw is a heavy casting, pivoted centrally near the crushing end. A horizontal, reciprocating motion is communicated to the other end by an eccentric. This is a very efficient crusher for coarse work, being very powerful and having few wearing parts.

The Dodge Crusher (Fig. 5) differs from the Blake in that the oscillating jaw is pivoted

at the lower instead of the upper end (resembling the Krom crusher in this respect), from which it results that the product is more uniform in size, as the discharge opening remains nearly constant. It is obvious from this that it can be used to crush finer than the Blake, and that its capacity is smaller. The oscillating jaw projects in an arm to which an up-and-down movement is communicated by means of the eccentric on the driving-shaft at the rear of the machine. The jaw-shaft rests in movable boxes. To change the size of the material crushed, it is only necessary to loosen or tighten the adjusting screws, placing packing-blocks on either side of the movable boxes.

The Comet Crusher (Fig. 6) is a rotary coarse-crushing machine of large capacity. It consists of an upright spindle, *G*, carrying a cone-shaped crusher-head, *F*, which works in a circular hopper, *P*, fitted with a chilled-iron lining, *E*. The axis of the spindle is not coincident with the main axis of the machine or bevel-wheel, but intersects it in the journal at the top, while the lower end is from ¼ in. to ¾ in. (depending on the size of the crusher) out of center. This arrangement causes a gyrating motion at the bottom of the spindle, the top of the journal being practically stationary except in the slight motion due to the angularity, which is very small, and is compensated for by the oscillating box, *B*. The spindle, with its fixed crusher-head, *F*, is not fastened into the bevel-wheel, but is free to revolve in it. Crushing is caused by the moving of the crusher-head, *F*, to and from the liners, *E*, exactly as in a Blake or other similar crusher with reciprocating jaw motion, and as the entire space around the head is filled with rock, the crusher is doing duty at every point in revolution of the pulley and gears.

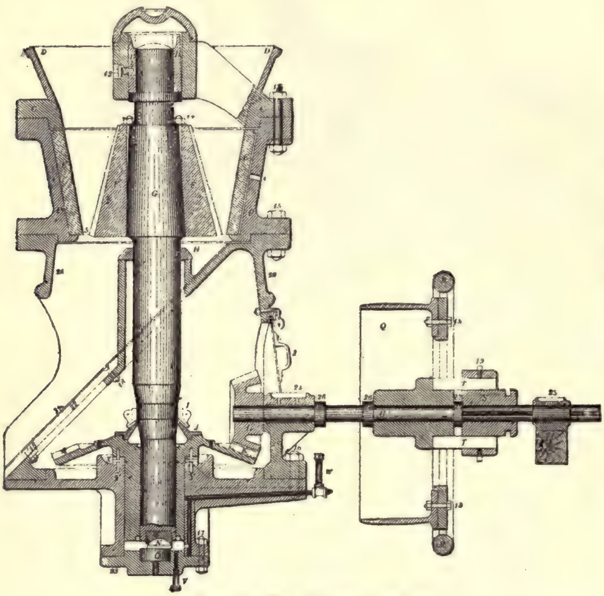


FIG. 6.—The Comet crusher.

The machine does not have a grinding action, as the head does not turn while crushing, although it is free to do so when not crushing. The crushed rock drops into the inclined chute and immediately slides out. This machine is especially designed for crushing railroad ballast and street macadam, but has also been used for coarse-crushing of ores, phosphate rock, etc. Messrs. Fraser & Chalmers, the makers, state that machines with a 6 × 12 in. opening will crush from 4 to 8 tons of rock per hour to macadam size, consuming 8 horse-power, while the largest machines made, 12 × 24 in., will crush from 40 to 60 tons per hour, with a consumption of 50 horse-power.

The Gates Crusher is similar in principle and construction to the Comet. Prof. H. O. Hofman states, in a paper on "Gold Milling in the Black Hills" (Trans. Am. Inst. Mining Engrs., vol. xviii.) that one of these crushers, lately installed at the Caledonia mill, at Terraville, S. D., with three receiving openings, each 12 × 18 in., attended by one man, crushed 200 tons of ore in 10 hours, with about the same horse-power as three No. 5 Blakes, and set to the same size as the latter. When the three Blakes were in use, it required 20 hours and 5 men to produce the same result. The disadvantage of both the Gates and Comet crushers is their enormous weight, and the consequent difficulty of transporting them, especially in many mining regions in rough and mountainous parts of the country.

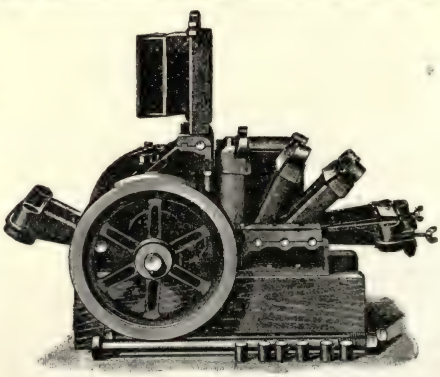


FIG. 7.—Blake multiple jaw crusher.

FINE-CRUSHING MACHINES.—*The Blake Multiple-jaw Crusher* (Fig. 7) is constructed upon the same principle as the ordinary Blake crusher, but is designed for finer crushing. In this machine the crushing is done

between a series of sliding jaws supported upon the main tension-rods. The jaws are separated and held by rubber rings placed between them on the tension-rods. In Fig. 7 this crusher is shown with the jaws thrown open, as if to put in new crushing-plates, or the like. The method of imparting motion is the same as in the regular Blake crusher—*i.e.*, by means of eccentric, pitman, and toggles. The revolution of the shaft bringing the toggles more nearly into line, throws the main sliding jaw forward, thus compressing the whole series of sliding jaws, the crushing pressure being transmitted through the material to be crushed, with which the jaws are supposed to be filled. It is evident that if a piece of iron or steel should by accident get into one of the jaws, the only result would be to render that jaw for the time inoperative, the motion that it would have with respect to the next succeeding one being taken up and distributed through the other jaw openings. The size of the jaw openings in the machines ordinarily used varies from 15 × 4 in. to 30 × 2 in. These crushers have not yet come into general use, but they promise much for the future. The construction admits of a great area of discharge opening, and since the breaking of each fragment of rock is accomplished by the approach of two opposing surfaces, which can never meet, all particles sufficiently fine are at once removed. They give a more direct blow than rolls, and the die and shoe do not come together, as in the case of stamps; hence, they make a comparatively small proportion of fines, and would seem to be particularly adapted for use in dressing-works. According to Mr. Theo. A. Blake, the present limit of crushing with this machine is from 14-mesh to 20-mesh, although it may be possible to carry it to 30-mesh. The largest installation of multiple-jaw crushers that has yet been made is at the dressing-works of the Chateaugay Ore and Iron Co., Lyon Mountain, N. Y., where all the ore is crushed by Blake machines, beginning with a single-jaw crusher of the ordinary type, and finishing with a series of multiple-jaw crushers of gradually diminishing size. The efficiency of this system is shown by the coal consumption, which was 1 ton of coal to 60 tons of ore, crushing from 15-in. size to ¼-in. size, on a fifteen months' run, from September 26, 1886, to January 1, 1888, a total of 137,551 tons of ore being worked.

The Improved Steam Stamp (Fig. 8).—One of the most important machines developed in the history of American ore-dressing machinery is the steam stamp, which, although invented in 1856, and manufactured ever since, has but lately been improved. These stamps are used exclusively for crushing ore for concentration at Lake Superior, and are extensively used in crushing copper-sulphide ore at the large dressing-works at Anaconda, Mont. A steam stamp has also been used in the Homestake gold-mill, at Lead City, S. D., with, it is said, poor commercial results. At Broken Hill, New South Wales, steam stamps have been erected for crushing silver-lead ores, but the results obtained there have not yet been published. The improved steam stamp is built entirely of iron and steel, the entire framing of the machine consisting of four massive cast-iron columns, braced to one another, and securely bolted together and to the heavy cast-iron sills or bed-plates, with body-bound bolts. The stamp is operated by a vertical steam cylinder, which can be made of any diameter or length of stroke, according to capacity required. The shaft operating the valves, by means of eccentrics and rods, is worked by a pair of machine-cut elliptical steel spur-wheels, receiving their motion from a countershaft driven from the mill line-shaft by a belt. This countershaft has a balance-wheel to insure steady motion. The irregular motion conveyed by the elliptical gears moves the valves in such a manner as to keep the top steam-port fully open for admitting the full steam pressure during the down stroke, and a small opening of the lower steam-port for the up stroke. The mortar has four discharge openings, and rests on a heavy cast-iron anvil or bed-plate 20 in. thick, weighing about 11 tons, which is carried by spring timbers that rest upon the lower sills. Between the anvil and spring timber is a rubber cushion, 1 in. thick. The angle guide-pieces cast on the columns hold the mortar in place. These guides are planed and fitted with gibs adjustable by set-screws and jam-nuts. Neither mortar nor anvil is held down by bolts. This construction gives a yielding foundation, and, consequently, a certain amount of vertical elasticity. Within the past two years the innovation has been made of doing away with the spring timbers under the mortar bed, and setting the anvil block on a solid, unyielding base of masonry, and the results at Lake Superior seem to have demonstrated that an increase in capacity is gained in this manner. With the anvil and mortar springing away from the hammer a certain percentage of the force of the blow is lost, while, with the solid foundation, the whole is utilized for pulverizing the material in the mortar. The upper and lower guides for the stamp-stems consist of cast-iron brackets fitted with removable bronze bushings, which can be replaced when worn. The stamp-stem is slowly revolved by means of a horizontal pulley on a cast-iron sleeve between the upper and lower guide-brackets. This sleeve is brass-bushed, and contains two feathers fitting in corresponding slots in the stamp-stem, by which the latter is rotated. The piston-rod is made of steel, and is connected to the stamp-stem by a circular disk, which is encased by a cast-iron bonnet bolted to the flange of the stamp-stem. The space between is filled with pure gum-rubber packing. This arrangement relieves the shock on the piston, and also permits removal of the piston for repairs without disturbing the stamp.

The piston is made of steel and fitted with bronze packing-rings, and is easy of access for packing and repairing when necessary. The water is fed in through the two nozzles shown on the top of the mortar, and from the circular chamber is thrown against the stamp-stem from every side, preventing it from being cut and worn by the sand. The ore-feed, or spout, is placed on top of the mortar, and is covered over to prevent any pieces of ore from falling

outside around the mortar. The speed of the stamp averages 90 blows per minute. The capacity of the 15 × 30 in. stamp averages about 150 tons fine-crushing, and about 230 tons coarse-crushing, per 24 hours. A stamp of this size weighs 70 tons. The new stamps at the Tamarack mill, Lake Superior, crush 225 tons per 24 hours, from 3-in. size to $\frac{3}{16}$-in., running at 90 to 92 strokes per minute; from 34 to 36 tons of ore being crushed per ton of coal consumed. Although the steam stamp makes a greater percentage of slimes than careful crushing by

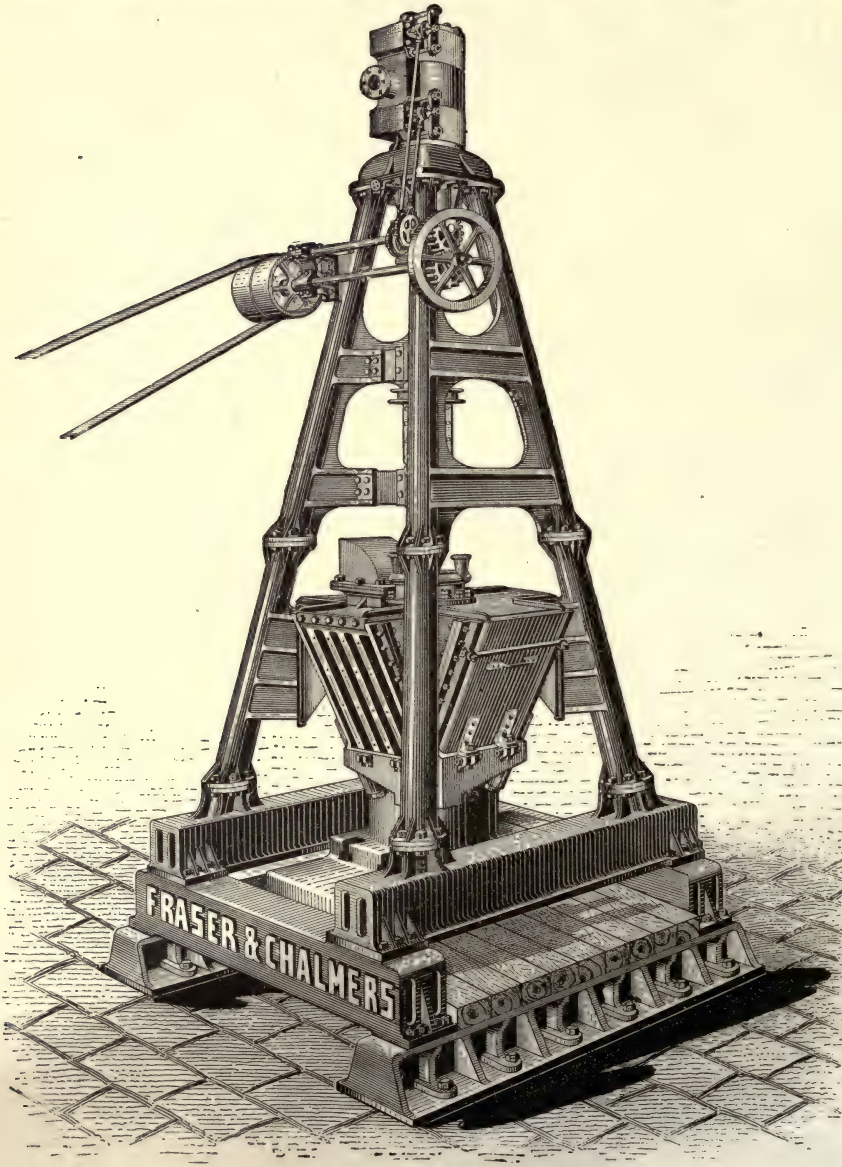


Fig. 8.—Steam stamp.

rolls, by its rapid and enormous delivery it makes less slimes than gravitation stamps, as has been proved by crushing the same kind of ore in both ways for pan amalgamation—a steam stamp having been used for the latter purpose by the Anaconda Mining Co., at Anaconda, Mont.

Gravitation Stamps are still the means generally in use for crushing gold and silver ores for amalgamation and lixiviation. The tailings from the amalgamating plates in gold mills are frequently concentrated to recover the auriferous pyrites, but stamps are never used now in well-designed dressing-works, except, perhaps, for re-crushing middlings, unless it is

necessary to crush all the ore to the condition of meal or pulp. When ore is to be crushed to the size of fine sand only, even the best stamp-batteries are objectionable, because they reduce by far the greatest proportion of the ore—frequently over 90 per cent.—to a much finer condition than is required. Some important improvements have been made in the wearing parts of stamps, particularly shoes, dies, and guides.

Fraser & Chalmers' stamp-shoes are cast of two kinds of iron at the same operation, by a patent process. The body of the shoe is made of white-iron of the hardest quality, while the neck, or stem, forming the upper part of the shoe, is made of iron possessing almost the tenacity of malleable or wrought-iron. The two qualities of iron are thoroughly united when in an incandescent state, the point of union being below the bottom of the stem. The combination of extreme toughness where the strain is greatest, with exceeding hardness and durability of parts exposed to wear, makes these shoes, it is claimed, far more lasting and reliable than those made in the ordinary manner.

The chrome-steel shoes and dies, made of chrome-steel prepared by a special formula and process, which is kept secret by the manufacturers, have given excellent results. At the Utica mill, Angel's Camp, Cal., where chrome-steel dies and iron shoes are used, the wear of shoes, according to the *Eighth Annual Report of the State Mineralogist*, was 19 lbs., or 1·5 cents, per ton, of ore crushed, and 55 lbs., or 2·5 cents, of iron dies per ton of ore, making a total wear of but 4 cents per ton.

Broughall Stamp Guides.—These consist of a series of wrought-iron clamps and links enclosing wooden bushings, completely filling the space between the battery posts, being rigid, but fully adjustable. These guide clamps consist of two or more arms pivoted to keys, which are firmly secured to the guide rail. At their free ends each is connected by a link, having an outwardly movable part provided with a locking or pressure device, which is simply a clamp screw and lock nut bearing upon a plate, which protects the guide blocks from injury by the point of the clamp screw. By this arrangement any one set of the clamps can be loosened or tightened to properly adjust the bushings without interfering at all with the others. There is no wear on the iron clamps or links, nor are they shaken out of place or loosened by the regular, recurring blows of the stamps—a source of great annoyance, demanding constant attention, with the ordinary guides. By removing the upper bushings, the tappet can be taken off or put on any stem without stopping any other. By removing both upper and lower bushings, any stem can be taken out without removing either tappet, stamp head, or shoe, and without disturbing any other stem, and if desired the battery can be run with one or more stamps out for repairs.

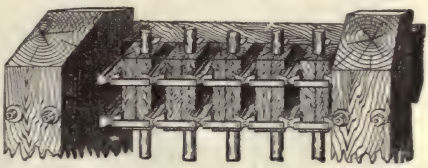


FIG. 9.—Fargo stamp-guides.

The Fargo sectional stamp guides (Fig. 9), for which are claimed the same advantages as the Broughall, consist of a series of iron keys enclosing wooden bushings, completely filling the space between the battery posts. The keys for each stem are arranged in pairs, connected at the outer end by iron bars, and at the inner end by the guide rail of the battery. The inner faces of each pair are inclined to each other with a broad bearing of each side of a bushing, and by tightening the nut on the inner end, will take up all wear in the bushing. Their outer edges are parallel, and tongued and grooved together. This admits of each pair of keys being moved, and its bushing tightened, without interfering at all with any other pair.

Cornish Rolls.—Cornish rolls, the typical form of all crushing rolls, consist of two iron rollers, from 9 to 40 in. in diameter, and from 9 to 16 in. face, their axles connected by strong gear wheels, and revolving in opposite directions. The shaft of one roller is in stationary bearings, the other being in sliding boxes, acted on by regulating heavy springs or weighted levers, so that a uniform pressure is maintained between the faces of the revolving rolls to crush the rock introduced between them. The rolls are fitted on the outside with shells of hard iron or steel, and these can be replaced by new ones when worn out. Of late rolls have generally been built without the gear-wheel connections between their shafts, but each run independently by belt pulleys, a greater speed of rolls being employed, with consequent increase of capacity, and the annoying wear of gearing avoided. This important improvement is principally due to Mr. S. R. Krom, of New York, whose name is famous in connection with the design of crushing rolls, and the innovation was first made at the Bertrand mill, in Nevada, in 1883. The rolls which were introduced at that mill were designed to run at 100 revolutions per minute ; it is impossible to drive geared rolls, with safety, at a greater speed than 40 to 50 revolutions per minute. Since the installation at the Bertrand mill much higher speeds have been used successfully, but 100 revolutions per minute is the average rate now employed.

The shells used on the rolls may be either chilled white iron or mild steel. The former are the harder, but they become nicked by excessively hard lumps of ore, or pieces of steel, which may, perhaps, pass through them, and thus lose the smooth surface which is necessary for good work. The mild steel has the objection of retaining these pieces of steel, thus chiseling the face of the shell as if it were in a lathe. This disfigurement and damage is usually averted by the use of magnets similar to those used in flour mill grain chutes. Unless fed properly, they, like all other shells, wear hollow in the center. It is not generally known that the chilled iron may be turned, and shells of this material are usually

thrown aside when too badly worn. Dr. E. D. Peters states, however, in his *Modern American Methods of Copper Smelting*, that the hardest chilled iron may be turned with an ordinary tool without difficulty if a sufficiently slow motion is used in the process. Steel shells, which may be turned quite easily, have, on the whole, given greater satisfaction than the chilled iron, and are, at the present time, more generally in use.

The size of the rollers is a matter of great importance, and the tendency of late years, on the part of many engineers, has been to increase the diameter—rollers of 36 in., 1 meter, or even 40 in. in diameter being now not infrequent. The larger the diameter, the larger the size of the lumps of ore which can be crushed, and with lumps of ore of a given size, the greater the capacity and the less fines made, the lumps of rock receiving a more direct crushing blow and less grinding action.

Rolls make a smaller proportion of fines than stamps or any of the grinding machines, and are, consequently, especially adapted for the final crushing for concentration. Within the past ten years their use for very fine crushing in lixiviation mills has been advocated, and they have been thus employed in several mills with fairly successful results, although they have not yet come into general use for this purpose.

Krom's Rolls (Fig. 10) are the standard type of Cornish rolls in use in this country at the present time. They are constructed after the same general pattern as the ordinary rolls, but differ in several details, which are, nevertheless, of much importance. In most of the ordinary rolls, one pair of pillow blocks is arranged to slide on the bed plate, and each one of the two sliding pillow blocks must be adjusted separately. It requires great care to bring up two separately movable pillow blocks evenly and parallel with the stationary ones, and any looseness between the faces of the movable pillow blocks and the bed plate results in damage to the machine. In some rolls the difficulty of adjusting the movable roll is overcome by connecting the sliding pillow blocks so that they move together, and are thus kept always parallel with the face of the fixed roll. Mr. Krom has gone still further, however, and introduced a device which not only keeps the two rolls always parallel, but obviates the wear of sliding pillow blocks on the bed plate almost entirely. This is accomplished by means of the swinging bearings, the construction of which is shown in Fig. 11. The movable roll being supported in this manner, both ends must swing together, and as the bearing does not slide on the bed plate at all, simply swing from it, there is obviously much less wear there. These swinging bearings are made so strong that the roll will maintain its parallel position if the bearing is bolted to the bed frame at one end only. The shells, which are made of hammered steel, such as is used for locomotive tires, are held on by two heads, slightly cone-shaped. One of these heads is securely fixed to the shaft by shrinking on ; the other is split on one side, so that, when the heads are drawn together within the shells by bolts, the split head will close tightly upon the shaft. The bearings are water-jacketed, so that in cases where the work is very severe and heavy, or when the machine is new, the journals can be kept cool by the circulation of water behind the bearings. These rolls are so covered by housings that ore can be crushed very finely, without the escape of dust, it is said, but an exhaust fan is generally used to collect the fine pulp. The rollers are designed to run at a speed of 100 revolutions per minute, and are always driven by belts. The capacity of a set of rolls varies principally with the fineness of crushing. A pair of 14 × 26 in. rolls, running at 100 revolutions per minute, should easily crush 20 tons of moderately hard ore per hour. From this maximum the capacity diminishes with the fineness. At the Bertrand mill, in Nevada, in 1883, two sets of Krom's 15 × 26 in. rolls

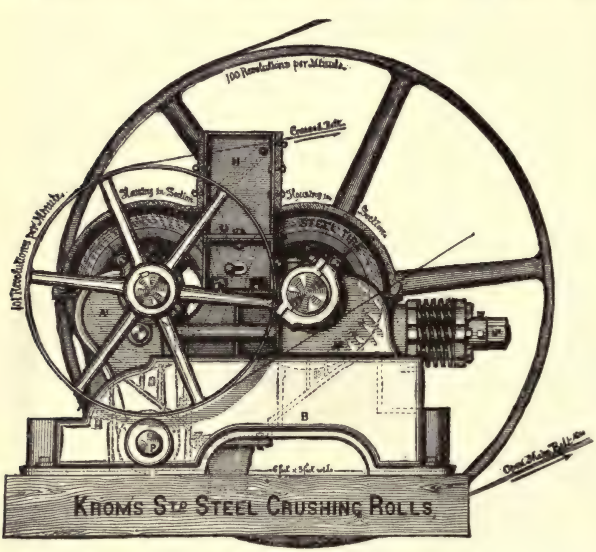


FIG. 10.—Krom's rolls.

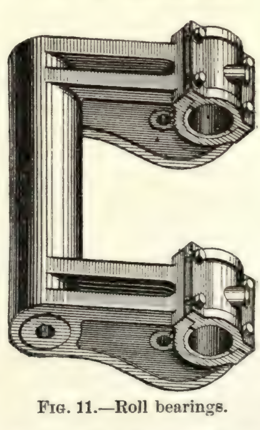


FIG. 11.—Roll bearings.

crushed 100 tons of hard quartzose ore, so as to pass a 16-mesh screen, in 24 hours, according to the statement of Mr. R. D. Clark, the superintendent of the mill, which is regarded by Mr. C. A. Stetefeldt (Trans. Am. Inst. Mining Engrs., vol. xiii. p. 114) as equivalent to the work of 30 stamps, of 850 lbs. each, dropping from 7 in. to 8 in., 94 times per minute. This statement is controverted, however, by other mechanical engineers who have had opportunities of examination of the plant under its normal condition. In the same paper, Mr. Stetefeldt, basing his figures upon the data furnished by the Bertrand mill, and three prominent stamp mills in the West, estimated that the saving in a mill equipped with two sets of Krom's 26-in. rolls, as compared with 30 stamps, was $27.23 per day, of which $10.55 was in wear and tear and repairs, $4.68 in interest and amortization, and $12 in fuel. Mr. S. R. Krom states that the capacity of the rolls at the Bertrand mill was subsequently rated at 150 tons per 24 hours, crushing to pass a 16-mesh screen. At the Mt. Morgan mill, Queensland, Australia, eight sets of rolls are used, crushing to 40-mesh fineness, at the rate of about 37½ tons per 24 hours per set. The Mt. Morgan ore is, for the most part, easy crushing, but even considering that fact, this is certainly a remarkable result.

Buchanan's Straight-line Crushing Rolls are a modification of the ordinary type of Cornish rolls. The journals of the sliding roll are cast in one piece, the standards of the journals being connected by a strong cross-bar, strengthened by heavy ribs. There are heavy slides on the bed frame, and the entire top of the latter is planed, so that the sliding roll is compelled to move in a straight line, its face being always parallel with that of the fixed roll, when giving to pass a piece of material too hard to crush, such as a drill point. The makers claim that this straight-line movement causes the rolls to wear more evenly, and avoids end play of the rolls.

Bowers' Rolls are constructed upon the principle of ordinary Cornish rolls, differing only in the shape of the roll faces. With careless and improper feeding, the faces of cylindrical rolls wear concavely. To compensate for this, the Bowers rolls are made with the face of one concave and the other convex. Rolls properly fed wear regularly enough, however, and as the advantages gained by the Bowers system are more than balanced by the disadvantages, they have not come into general use.

The Heberle Mill, one of the standard types of fine-crushing machines, consists of a cylindrical drum, in which is a large plate slowly rotating on a horizontal axis, and two small,

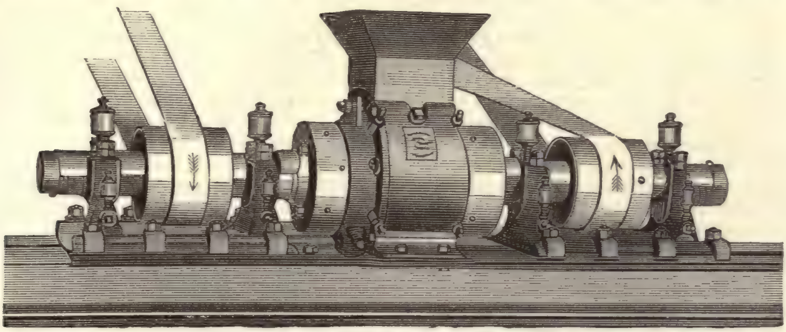


FIG. 12.—Sturtevant mill.

rapidly revolving runners, each having a plane annular grinding face and a coned center. Both of the runners are set on the same side of the turning plate, very close to and parallel with it, and in the fields of its lower quadrants. The large turning plate is pierced by a number of holes set radially and in a ring, so as to form in it a circle of apertures. Ore, supplied by launders to one side of the plate, passes, during the revolutions of the latter, through the apertures, and falls directly into the narrow slit between the inner edge of the grinding face of each runner and the wearing surface of the plate. Seized by the runners, and partly ground and partly sheared, the ore is reduced, and drops out through the bottom of the machine. The closeness of the runners to the plate, and the pressure they exert upon the ore, can be accurately adjusted by hand screws and rubber resistance buffers. The wearing parts of the machine are made so as to be easily replaceable. Shoes on the runners last about 960 hours. According to W. B. Kunhardt, in his book, *The Art of Ore Dressing in Europe*, the machine works to poor advantage and with small capacity on ore above 5 mm. ($\frac{1}{5}$ in.) in size. It is generally used for grinding to a fineness of 1 mm. ($\frac{1}{25}$ in.) to 2 mm. ($\frac{2}{25}$ in.), but the reduction has sometimes been carried down to 0·75 mm. As the result of long-continued working at Przibram, the quantity of quartzose ore crushed down to 2 mm. size by a Heberle mill with two runners was as follows: 2,466 lbs. of 4-mm. ore per hour; 1,368 lbs. of 6-mm. ore; and 1,157 lbs. of 9-mm ore. Under the most favorable conditions the consumption of water in crushing was 5.4 gallons per minute for each runner. The percentage of slimes made is small compared with many other machines, and the Heberle mill is, consequently, especially adapted for fine-crushing in dressing works. For further details see *Berg und Huettenmannische Zeitung*, vol. xi. p. 400, 1881.

The Sturtevant Mill (Fig. 12).—The crushing and grinding parts of this mill consist of two cylindrical heads or cups arranged upon the opposite sides of a case into which they

slightly project, and, facing each other, are made to revolve in different directions. The rock or ore to be reduced is fed into the opening at the top of the case, and passing down to the interior, is prevented from dropping below the revolving heads by a cast-iron screen, and entering, as it must, the heads or cups in revolution, is immediately thrown out again from each cup in opposite directions with such tremendous force that the rock or ore coming in collision is crushed and pulverized, and the grinding, which would otherwise be upon the mill, is transferred to the material, which is at once reduced to any fineness desired, determined by the size of opening in the screen used. The material, as fast as ground, passes through the screen, and falls into the bin. When necessary to reduce the rock to a greater fineness than the screen outlets allow, the coarser part of what leaves the screen is reconveyed to the mill by an elevator, for regrinding, that which is already sufficiently fine being first removed by the usual apparatus adopted in milling. A suction blower causes the air to draw strongly into the mill, and prevents the escape of dust. The cast-iron screen is composed of small sections, and the worn parts are cheaply and easily replaced. It is claimed that the wear upon this screen is very slight, as it is always protected from the action of the rocks thrown from the heads or cups by a cushion of interposing material, formed by the rocks which always fill the case and cover the screen.

The manufacturers of this mill furnish the following data :

Size of mill	Largest size material to feed mill.	Capacity in lbs. per hour to pass 10 mesh.	Capacity in lbs. per hour to pass 40 mesh.	Outside dimensions of mill, length and width.	Weight of mill in lbs.	Horse-power required.	No. of rev. per minute.
in.				ft. in. in.			
6	2″ cube.	500 to 1,000	....	4 ·7 × 26	1,100	10	2,600
8	2½″ "	1,000 " 3,000	500 to 1,100	6 ·9 × 28	2,335	20	2,000
12	3½″ "	10,000 " 20,000	2,000 " 8,000	9 ·7 × 35	4,625	45	1,300
20	4½″ "	15,000 " 30,000	4,000 " 10,000	14 ·8 × 56	17,775	75	850

This is an excellent mill for fine-grinding, and a large number of them are in use for comminuting phosphate rock, copper matte, etc. They have lately been introduced for grinding iron ore for magnetic concentration with very good results. Mr. W. H. Hoffman gave the results in crushing with this mill at the Croton magnetic iron mines in a paper read before the American Institute of Mining Engineers, as follows : The screen-block openings were ¼ in. wide, and the coarsest material passing through them was less than $\frac{1}{32}$ in. thick, while the finest material would be rejected by a 60-mesh screen. The ore entered the mills at a temperature of about 350°, under which conditions it was quite friable, and there was no difficulty in grinding 22 tons per hour with a 20-in. mill, and 16 tons in the same time with a 15-in. mill. One set of bushings will grind from 4,000 to 6,000 tons of ore, according to the depth of the chill in the bushing, the cost of each set being $16. The screen blocks for this amount of ore cost $9. At 22 tons per hour the 20-in. mill requires 94 horse-power, and the 15-in. mill 70 horse-power.

The Cyclone Pulverizer consists of a small iron cylinder, in the base of which are two small iron fans, resembling propeller screws, which are rotated in opposite directions at great velocity, creating counter currents of air of great force, which take up the particles of the material with which the machine is fed, grinding them by their impact and attrition. The velocity of the fans ranges from 1,800 to 3,000 revolutions per minute. At the upper part of the machine is a hopper into which the ore to be pulverized is delivered : connected with the hopper is an automatic device which feeds the material regularly into the machine. The degree of fineness of the grinding is regulated by an adjustable fan, which causes a draft of air through the machine. If the product is desired coarse, the draft is increased, and the product thrown into the collecting chamber before it is reduced to a powder ; if the product is desired excessively fine, the draft is made slight, thereby allowing the material to remain longer in the machine. This machine is adapted for very fine grinding only. Mr. Axel Sahlin, in a paper read before the American Institute of Mining Engineers, October, 1891, stated that puddle slag was ground with this machine at Boonton, N. J., so that the coarsest particles would pass a 225 mesh sieve, at a cost of $1.50 per ton, the capacity of the machine being about 900 lbs. per hour.

The Frisbee-Lucop Mill (Fig. 13) is a centrifugal roller mill in which the rolls are driven around against the inner periphery of a heavy steel ring, set vertically in a suitable iron casing. The ring is immovable ; the rolls, two in number, are held loosely in position between a pair of annular disks, or disk-plates, firmly bolted to a central arm, which latter is keyed to the shaft. Between the disks also are fastened two cylindrical drivers, one for each roll, which pushes or drives it around as the mill revolves. The revolving parts are thus the arm, disks, drivers, and rolls, all of which have a motion uniform with the shaft ; the rolls have in addition an independent motion around their axes. The separation of the fines from the coarse is effected within the mill, either by air-blast or by suitable screens. The casing on each side of the mill is divided by a vertical screen of suitable fineness, set transversely to the shaft. Fan-blades are attached to the outside of the disks, by which the material, as

fed into the mill, is distributed around the inner periphery of the ring in the path of the rolls, to insure an equal amount of work at every point of the face of the ring. Exterior to the screens on each side is a circulating fan, which causes a current of air to pass outward through the screens, and discharges the finished product through chutes passing downward through the bed plate. The casing is divided horizontally, and the upper and lower halves are held together by hinged bolts in slots cut in the flange of each section. The upper half is hinged to the lower at one side, and can be raised so as to give free access to the interior of the mill for examination and replacing worn parts.

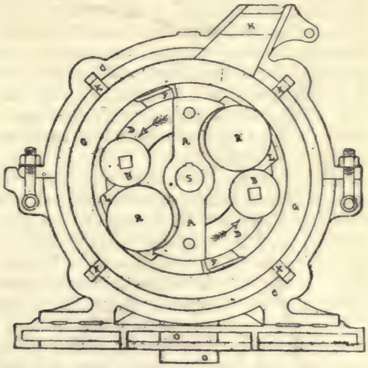


Fig. 13.—Frisbee-Lucop mill.

A revolving screen of coarse mesh, attached to the shaft inside of the fixed screens, prevents any piece of iron or large fragments of rock from coming in contact with the fine screen, but does not prevent the finished product from passing freely. This revolving screen is unnecessary with quartz or other hard material, and is used only when clay, cement, talc, or some such material is ground, when the mill is entirely full of the rock. The material to be ground is first passed through a crusher to a size of ¾ in. or less, as may be convenient, and then fed by a chute directly on the feed shoe. The mill should be used for dry work only. The mill is built in two sizes, 24-in. and 20-in., these dimensions being the inner diameter of the ring. The 24-in. screen mill weighs 5,500 lbs. It will grind, according to its manufacturers, about 2,000 lbs. of quartz per hour to 60-mesh powder, and up to 6,000 lbs. per hour of softer material. Speed, 300 revolutions per minute, requiring from 15 to 18 horse-power, according to hardness of material ground. The 20-in. mill weighs 3,800 lbs. It has a capacity of 1,000 lbs. of hard quartz per hour to 60-mesh powder. Speed, 500 revolutions per minute, requiring about 8 horse-power. In the Frisbee-Lucop blast mills the screens are omitted, and the pulverized material is separated from the coarse by gravity, being drawn from the mill, as generated, through pipes connected with the top of the casing, and carried to chambers prepared for it, by an exhaust fan or other method of causing a current of air to pass through the mill. This mill is claimed to be especially adapted for grinding phosphate rock and like substances.

The Frisbee-Lucop Wet-crushing Mill is constructed upon the same principle as the dry-crushing. It has double screens at each end—coarse ones on the inner side, which take the wear of the coarse rock, and fine screens beyond (which may be of any mesh), to finish; nothing can leave the mill until fine enough to pass the outer screen, the coarse stuff passing the inner screen going back under the rolls. The annular die, or ring, on which the rock is crushed, is of rolled steel, 24 in. inside diameter, 3 in. thick, with 6 in. face. The rollers are 9¼ in. in diameter by 6 in. face, with a tire of forged steel. The capacity of this mill is claimed to be 3 tons per hour of hard quartz to 40-mesh, up to twice that amount for soft material and coarse pulp.

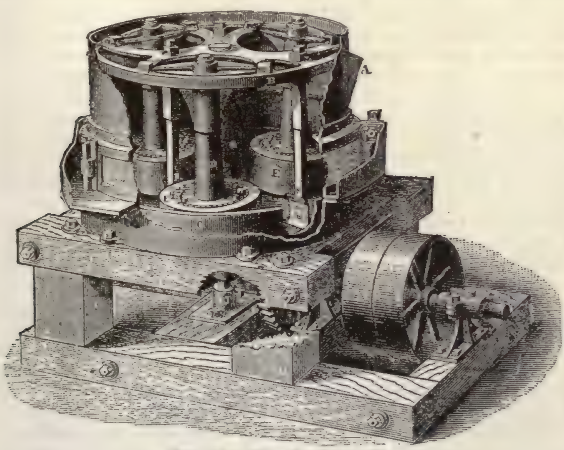


Fig. 14.—Huntington mill.

The Bryan Mill is a modification of the well-known Chile mill, arranged for the continuous wet-crushing of either gold or silver ores, eliminating, it is claimed, all that is objectionable in the Chile mill. It consists of an annular mortar, containing fixed segmental steel dies arranged in the path of its three crushing rollers. The axles of the rollers are journaled in a central revolving table attached to and driven by the belt pulley directly. The 4-ft. mill has a similar arrangement of dies, but smaller rollers, whose weight is increased as desired by the load carried in the pulley drum, which rests on their periphery, thus adding to their weight, and driving them by friction. The pulverized ore is discharged through screens in the side of the annular mortar. This mill has a peculiar advantage, inasmuch as its weighting, upon which its crushing capacity, like other mills, depends, can be done at the mine by placing either shoes, dies, or even stones in the pulley, virtually a pan which bears upon the rollers. Thus heavy transportation is avoided in comparatively inaccessible districts.

Jordan's Reducer, sometimes used in crushing gold ores for amalgamation in connection with Jordan's amalgamator (see GOLD MILLS), is a revolving pan, set at an angle, and carrying three massive balls of white iron, which work in a suitably shaped bed, also of white iron, round the greatest circumference of the pan. The ore and water are fed automatically into the bed of the pan, and by the rotary motion of the latter, are conveyed under the rapidly revolving balls, whereby the comminution of the ore is effected. The inner half of the floor of the pan rises as a shallow dome surrounding the central shafts, and is fitted with movable frames carrying wire screens of any required mesh. The feeds of ore and water, and the inclination of the screens, are so adjusted that, as the ore is reduced to a sufficient degree of fineness, it is washed over the screens and passed away into a launder for conveyance to the amalgamator. It is claimed that this machine has reduced 20 tons of ore in 24 hours, so as to pass an 80-mesh screen.

The Huntington Mill (Fig. 14) consists of a spindle, *G*, carrying a circular frame, *B*, at its top, from which are suspended four steel rollers, *E*, which are rotated against a ring, forming the base of a mortar or pan. The ore and water being fed into the mill at the hopper, *A*, the rotating rollers and scrapers throw the ore against the ring die, where it is crushed to any desired fineness by the centrifugal force of the rollers as they pass over it. The water and pulverized ore are thrown against and through the screens when fine enough. The rollers are suspended, leaving a space of 1 in. between them and the bottom of the mill, thus allowing them to pass freely over the quicksilver and amalgam, without grinding it or throwing it from the mill, while it agitates it sufficiently to insure amalgamation. This mill is used for crushing and amalgamating gold ores, with excellent results. It is also employed for fine-crushing in dressing works, but its use for that purpose is not to be recommended, as it slimes the ore excessively. The manufacturers furnish the following data :

Size.	Weight.	Revolutions.	Capacity.	Power.
3½ ft. diameter...............	7,000 lbs.	90	12 tons.	4 H. P.
5 ft. "	11,000 "	70	20 "	6 H. P.
6 ft. "	20,000 "	55	30 "	8 H. P.

The Griffen Mill consists of a shallow cast-iron ring or mortar, which is surmounted by a tall sheet-iron cone, with an opening at the apex, through which a vertical shaft works. This shaft, which is driven by a horizontal pulley, has a universal-joint at its upper end—*i.e.*, just below the driving pulley ; while at its lower end is rigidly fixed a heavy cast-iron roller. The shaft and roller being free to move by means of the universal-joint, the roller is thrown against the side of the mortar or crushing ring by centrifugal force, and the rock or ore, which is fed in through an opening in the side of the case, is thus pulverized. The crushing roll swings several inches above the bottom of the mortar, but upon its lower side there is a plow which stirs up the ore in the bottom, and throws it against the ring die, where it may be acted upon by the roller. The crushed ore is discharged through screens in the case just above the ring die. A fan attached to the shaft above the roll causes the air to draw strongly into the mill, and prevents the escape of dust. This mill is extensively used for fine grinding, such as pulverizing phosphate rock, but is not adapted to work where the formation of an undue proportion of slimes is to be avoided. It is stated that it will grind 4 tons of South Carolina phosphate rock per hour, so that 75 per cent. will pass a 75-mesh screen.

The Narod Pulverizer, similar to the Griffen mill, consists of a shallow, heavy cast-iron mortar or pan, surmounted by a conical sheet-iron case, in which are revolved three iron rolls, carried loosely at the end of vertical shafts. The shafts are fixed in an iron casting at the top of the machine, having, individually, a radial play in order to allow for centrifugal motion, and the whole is rotated by a horizontal pulley at the top of the machine. The rollers, being loose on the shafts, are free to turn. The ore is fed into the machine at one side, just above the rollers, and is crushed against the side of the mortar. Each shaft is covered by a sleeve, fixed to the roller, and extending to the top of the shaft. On each sleeve, just above the roller, are two spiral fans which, according to the makers, take up the material after preliminary grinding, and keep it in self-frictional agitation until rendered fine enough to discharge through screen in the base of the machine. The sleeves on the vertical shaft serve as oil chambers for the rolls, and the main or central shaft, which is hollow, serves as oil chamber for the main journal. The main shaft is driven at 140 revolutions per minute. This machine has been used for pulverizing phosphate rock, etc., but, like the Griffen mill, does not seem to be adapted for anything but fine grinding.

Tustin's Rotary Pulverizer consists of a cast-iron cylinder, or barrel, hung horizontally upon two hollow trunnions. Within the barrel is a ring, of somewhat smaller diameter than the barrel itself, composed of chilled-steel bars, placed longitudinally and a small distance apart, like grate bars. Within this annular grate-bar ring are two heavy cast-iron rolls, which are nearly as long as the cylinder itself, lying loosely. The cylinder is turned slowly upon the trunnions. Ore is fed into a hopper at one side of the cylinder, and passes into the latter by means of a tube projecting through one of the hollow trunnions. The ore falls onto and under the rollers, and is crushed between them and the grate-bar ring. The crushed ore

falls between the bars, and, if fine enough, sifts out through the screens in the outer shell of the barrel. If not fine enough, it slides down over the screen until stopped by one of the ribs which support the grate-bar ring, and is carried upward by the rotation of the barrel until nearly overhead, when it drops back to the interior through the apertures in the crushing (grate-bar) ring, and again falls between the rollers. The rollers lie naturally at the lowest point in the circumference of the barrel, and if the machine is properly fed, they remain approximately in that position. If the feed is scant, however, they oscillate right and left, like a pendulum ; in so doing they strike a horizontal yoke, fixed at the end of a shaft passing through the hollow trunnion opposite the feed trunnion, and by a pointer at the other end of this shaft, outside the barrel, give warning to the attendant ; or, this pointer may be connected with an automatic feeder, and regulating the latter, insure absolutely constant feed. The best work done by this mill is on rock broken to 1½ in. size, or smaller. The makers claim that, owing to the free escape of the crushed ore through the slotted dies, and the ample screen surface, it is almost impossible for the rollers to run more than once over a grain small enough to pass the screen, and that for that reason a high percentage of the ore grains are nearly of the same size as the screen, and but very little slime is made.

Ore Feeders.—Regular feeding is an essential in securing the maximum efficiency from any crushing machine, and where possible this is accomplished by automatic devices. It is usually necessary to hand-feed coarse-crushing machines, such as the Gates or Blake crushers, where the lumps of rock are of large and irregular size; but to the fine-crushing machines—stamps and Huntington mills, which are invariably run on rock broken previously to a comparatively small and uniform size, automatic feeders are well adapted and are almost a necessity. Not only is the efficiency of the crushing machine increased by this means, but there is a saving in labor, as one man can attend to a greater number of stamps or machines fed automatically than if fed by hand only. Nearly all ore feeders in common use are of the same general type, consisting of a sheet-iron hopper from which the ore is discharged regularly by some device actuated by one of the stamp stems, or some other regularly moving part of the crushing machine.

The Challenge Ore Feeder consists of a hopper, below which is fixed a cast-iron plate, the latter being inclined at an angle to the receiving aperture of the crushing machine. The plate is rotated by a bevel gear, which in turn is moved by a lever, which is struck by the tappet on the stamp stem, the motion being communicated to the gear through an ingenious friction device. At each partial rotation of the plate a small quantity of ore is scraped off by stationary wings, projecting from the hopper, which rest upon it. One feeder is used for each battery of five stamps. This feeder is an especially good one for wet ores.

The Fulton Ore Feeder has a roller with wide, shallow, spiral corrugations, placed below a sheet-iron hopper. The ore slides down in a shallow stream onto the top of the roller, which discharges it regularly and continuously. Just enough pitch is given to the corrugations of the roller to have one commence discharging at one end of the roller when the preceding one has finished at the other. The roller is turned by an adjustable pawl movement, actuated by a lever struck by a stamp tappet, as in the Challenge feeder.

The Tulloch Ore Feeder consists of a similar hopper, below which is suspended an inclined tray, by four short iron rods, from the same frame that supports the hopper. The tray is swung backward and forward by a system of levers actuated by one of the tappets of the stamp battery, just as in the Challenge feeder. The back of the hopper has an adjustable scraper, and at each motion of the tray a portion of the ore is scraped forward to the battery.

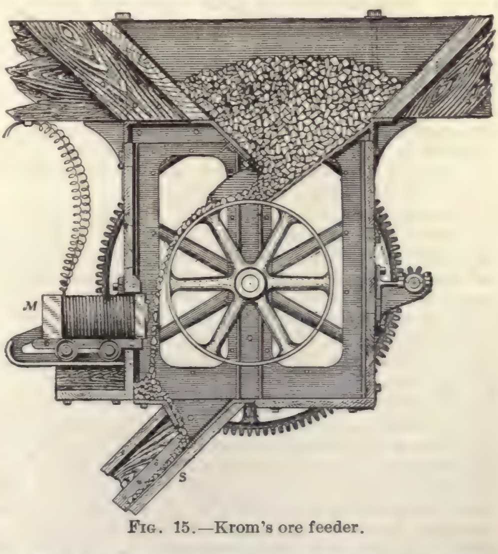


Fig. 15.—Krom's ore feeder.

Krom's Ore Feeder (Fig. 15), designed for feeding crushing rolls evenly and regularly, consists of a hopper discharging over a slowly revolving cylinder, the flow of ore over the latter being regulated by a gate at the bottom of the hopper. The revolving cylinder is driven by a large geared wheel and pinion, and the pinion shaft being driven by a cone pulley, its speed can be adjusted thereby. The minimum speed required is about 4 revolutions per minute ; the maximum, 10 revolutions. In front of the revolving cylinder is an electro-magnet, before which the stream of falling ore passes. Any pieces of iron or hard steel mixed with the rock or ore, such as drill points, which might damage the rolls, are thus caught. The electro-magnets are drawn back at intervals, and the pieces of iron and steel collected are dropped by cutting off the electric current. A regular feed for rolls is an essential point

not only for prolonging the life of the shells, but for securing the maximum efficiency in crushing, and this feeder has given excellent results.

ORE-DRESSING MACHINERY. DRESSING WORKS. (See ORE-CRUSHING MACHINERY).—Ore dressing is the art of separating the mineral in ore from the worthless rock or gangue, with which it is intermingled, the mineral, thus concentrated, being subsequently treated by the proper metallurgical process. In dressing ores mechanically, there is always a loss in values, varying from 10 per cent. to 50 per cent., or even more, and it is not customary to subject to this form of preparation ores which can be directly treated economically by any of the ordinary metallurgical processes. Mechanical dressing is, consequently, only resorted to when the cost of the operation and the loss in values is more than balanced by the saving in freight and in the cost of the subsequent treatment of the ore, gained by the elimination of the worthless gangue.

The method of mechanical ore dressing, in general, consists in crushing the ore to sufficient degree of fineness to free the particles of valuable mineral from the gangue, and afterward effecting a separation between the two by virtue of the difference in specific gravities. Two classes of crushing machinery are commonly used in every dressing works, viz.: coarse-crushing and fine-crushing. The former, of which the well-known Blake crusher is a type, takes the coarse lumps of ore as they come from the mine, and breaks them to a convenient size to be received by the fine-crushing machine, which may be a set of Cornish rolls. In most mills there are two sets of rolls in each crushing system, the final comminution being done in the second, which are set closer together than the first. Between each crushing machine and the next in series there should be a screen, over which the crushed ore is passed to remove the particles already crushed finely enough, thus relieving the following machines and preventing this ore from being crushed finer than is necessary, an important point, as the fine ore becomes slime, when mixed with water, which will probably give rise to increased loss in the dressing. Similarly, the ore is frequently dumped over a grizzly (a coarse screen composed of parallel steel bars), before being fed to the first crusher. The crushed ore coming from the finishing rolls is passed over a screen, the mesh of which constitutes the standard of crushing of the mill. That which will not pass through this screen is returned to the rolls; that which passes is sized in preparation for the washing machines. The sizing is done either by screens or hydraulic separators, but generally both systems are used in the same mill. With the former, the operation being technically known as "sizing," the particles of ore are divided into classes of equal size ; in a hydraulic separator the particles of ore settle against an upward current of water, and are thus classified into equal falling grains, the operation being technically known as "sorting." The usual practice in dressing works is to size by screens particles down to about 1 mm. in diameter. The finer particles are sorted. At Lake Superior, where there is a great difference in the specific gravities of the minerals to be separated—native copper and the various siliceous minerals which constitute the gangue—hydraulic classifiers alone are used. Screens, only, may be used in mills doing very coarse work, but never in a well-designed mill intended for fine and close work.

The sized and sorted ore goes from the screens and separators to the washing machines, by which the heavy particles of mineral are separated from the lighter particles of gangue, by virtue of the difference in specific gravities. Washing machines may be divided into two general classes, viz.: sand washing, represented by the various kinds of jigs; and slime washing, of which the various slime tables and buddles are types. The sized ore of which the particles are between 16 mm. and 4 mm. in diameter, is commonly designated as pea; between 4 mm. and 1 mm., as sand ; and finer than 1 mm., as meal. The pea and sand sizes are washed on jigs, the material from each sizing screen being conducted to a jig properly designed and adjusted for that size. The meal sizes, from the hydraulic separator, are washed on the slime machines ; the coarsest meal is worked on jigs, varying from the coarser jigs only in details of design, speed, etc., while the finer meal is conducted to other machines adapted to the size and character of the ore. With the washing machines the operation of dressing is completed, and the concentrates are ready to go to the smelting works, or elsewhere, for further treatment.

The cost of dressing varies, of course, with the capacity of the mill, the character of the ore, and the quality of the work done. The following are a few instances of the best American practice: At the Atlantic mill, Lake Superior, siliceous copper rock containing from 0·9 per cent. to 1·00 per cent. native copper has been dressed (1886) at a cost as low as 26·5 cents per ton, about 70 per cent. of the mineral being saved. The cost may be subdivided, assuming the same percentages as in the previous year, about as follows : Labor, 35 per cent.; fuel, 47·5 per cent.; supplies, etc., 17·5 per cent. The cost of dressing in this mill in 1890 was 27·78 cents per ton. At the mill of the St. Joseph Lead Co., at Bonne Terre, Mo., ore was dressed in 1887, according to Prof. H. S. Monroe (Trans. Am. Inst. Mining Engrs. vol. xvii. 659), at a cost of 36·4 cents per ton, divided as follows : Labor, 13·4 cents : repairs, 10 cents ; supplies, 3·5 cents ; coal, 9·5 cents. At this mill all the water used has to be pumped to the crusher floor; and all the tailings are carried off in cars, disadvantages under which the Atlantic does not labor, so that in making a comparison between the two, it is only fair to deduct 10 cents per ton, in Professor Monroe's opinion, from the St. Joseph figures. The St. Joseph ore is galena with a magnesian limestone gangue, assaying from 7·5 per cent. to 8 per cent. lead. The capacity of the mill is 800 tons per day. The loss in tailings amounted to 27·4 per cent. of the mineral. At the Hecla Consolidated Mining Co.'s mill at Glendale, Mont., ore assaying 7 per cent. lead and 15 oz. silver per ton, was dressed, in 1890, at a cost of 41·47 cents per ton, 55 per cent. of the

lead and 37½ per cent. of the silver being saved. The average cost of dressing low-grade ore in the silver-mining districts of the Rocky Mountains, in small mills, say of 100 tons per day capacity, is probably between 75 cents and $1 per ton.

PICKING TABLES.—In ore dressing it is frequently found to be advantageous to sort the ore before it goes to the fine-crushing machinery which prepares it for the hydraulic machines—picking out the pieces of rich mineral, which do not need to be concentrated, and also the waste or worthless rock. This is often done by hand by men or boys, who go over a lot of ore spread upon a platform, breaking the lumps of ore with spalling hammers to free the pieces of rich mineral, and throwing them aside into separate piles. A more economical and systematic method is to discharge the coarsely-crushed rock from the rock breaker upon a continuously moving table, beside which are stationed boys who pick out the pieces of good ore or gangue as they pass. Picking tables are usually made either in the form of broad, endless belts or circular rotating platforms. In the belt tables the crushed ore is made to drop on it at one end, is carried forward by the travel of the belt, being picked over in the meanwhile, and is discharged into chutes at the other end. The rotary tables generally consist of a large annular platform, covered with punched iron plate and revolving slowly (see Fig. 1). The coarsely-broken rock falls on it from a chute, spreading out, and is carried by the revolution of the table, until, meeting an inclined scraper, the whole is pushed off into the delivery spout. Standing around the table are boys who pick out by sight the large pieces of pure mineral or gangue, which are easily distinguished in the slowly moving layer of ore.

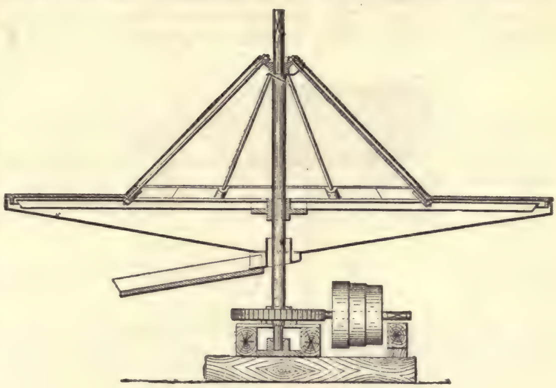


FIG. 1.—Rotary picking table.

ELEVATORS.—Elevators are used for raising crushed ore from breakers or rollers, according to the arrangement of the mill, to the sizing screens. They are usually of the belt-and-bucket style, and driven by the upper pulley shaft. The elevator is generally inclined forward at the top to give a free discharge to the buckets, but in fast-running elevators the centrifugal force, as the belt passes over the upper pulley, is sufficient to throw the sand into the chute, even when the belt is hung perpendicularly. An elevator's capacity depends on the size and number of buckets and the speed. Elevators of this kind are encased with wood to prevent loss of spilled material and slopping of water. The lower end, in which the lower pulley is fixed, may be a continuation of the wooden casing, or may be an iron boot with a belt tightener. The belt is always of four or five-ply rubber belting of good quality, and the buckets, of heavy sheet iron or steel, are fastened to the belt by countersunk bolts.

The Link-belt (*chain*) *Elevator* consists of a series of iron buckets carried or fixed to an endless chain, instead of to a belt, making a combination of great durability. For ordinary duty a single chain is sufficient, but for great duty and wide buckets two chains side by side are used. The average speed of an elevator is about 200 ft. per minute.

Sand Wheels are a special form of elevators employed at the Lake Superior dressing works for raising the vast quantity of tailings to such height that they can be sluiced to the place of deposit, the contour of the ground on which many of the mills are built being such that this can not be done naturally. The great wheels used at the Calumet and Hecla mills, which will serve as a type of all, are built upon the principle of those used on bicycles, with all spokes in tension. These spokes are in two systems—a set of conically divergent radial spokes for lateral stability and to support the rim, and a set of smaller tangent spokes for driving. The shaft and hub are of gun-metal, cast hollow, in three pieces, and about 23 ft. 8 in. long over all. The greatest diameter of the spider of the hub where the spokes are attached is 7 ft. 4 in. The journals are 22 in. diameter and 40 in. long. The spokes are of forged steel, 3⅝ in. diameter and about 22 ft. long. The rim of the wheel is built up of 18 cast-iron segments bolted together, outside of which is an equal number of gun-iron gear segments. The pitch diameter of this gear is 54 ft., the number of teeth 432, and the face of teeth is 18 in. On either side of this central rim a plate-steel frame is built, carrying internal buckets, making the total width of wheel rim 11 ft. ¼ in. The buckets are lined with wood to take the wear. The water and sand are delivered to the wheel by launders, which empty into the buckets on either side. At the top of the wheel on either side is an apron suspended from the roof trusses and extending into the wheel far enough to receive the water and sand delivered by the buckets, whence it is run off through other launders. The wheel is driven by a pinion which meshes into the gear before mentioned. The weight of each wheel complete, including the wooden lining of the buckets, is about 177 tons, and the weight of contained water and sand about 10 tons. The elevating capacity of this wheel is 30,000,000 gallons of water, containing 2,000 tons of sand, every 24 hours. This amount of sand is nearly sufficient to cover one acre, one foot deep, daily.

Sizing Screens.—Sizing screens are a very important part of a concentrating mill, as the success of the subsequent separation of the various constituents of the ore to be treated by the hydraulic machines depends upon the proper sizing of the particles. The ordinary sizing screen or trommel consists of a series of spiders, keyed to a shaft, over which is stretched wire cloth or sheets of punched steel or iron plate. The number of trommels and the mesh of the screens on them is regulated to suit the character of the ore treated and the degree of separation desired. The general arrangement of the trommels used in concentrating mills is shown in Fig. 2. Each trommel is geared to the one next to it, so that the whole line may

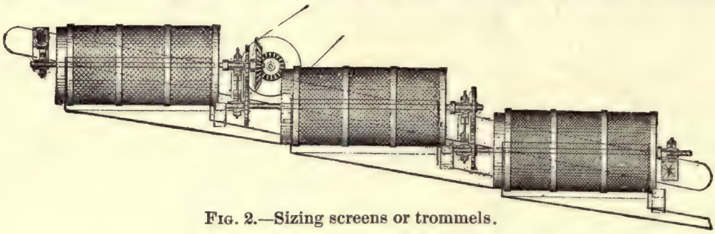


Fig. 2.—Sizing screens or trommels.

be driven from one point. The fine material from one screen passes to the next finer screen, and so on to the required number. The material remaining on each screen, and afterward discharged to the proper jig, is thus sized—*i.e.*, it has passed through the perforation of the preceding screen and will not pass through the perforations of the one retaining it. In dressing works the ore is invariably screened wet. The water for this purpose is sometimes fed through the shaft of the trommel, which is in this case made hollow, but usually from a perforated pipe hung above the trommel. Trommels are sometimes made of conical form, the axis being horizontal, and occasionally both cylindrical and conical screens are made with two sizes of wire cloth upon the same frame, making, in effect, a compound trommel. Concentric trommels, which consist of drums of different mesh, one within another, are never used now, the difficulty of repairing them making them highly objectionable in a mill. It is not usual in well-designed dressing works to use screens finer than 20-mesh, as the material which will pass that size is better prepared for the slime jigs and tables by hydraulic separators, and the finer screens wear out too fast, increasing expenses for repairs, and causing undue loss of time in patching or recovering them.

Hydraulic Separators.—Hydraulic separators are machines for classifying the fine material to be concentrated into groups of particles which, under like conditions, fall through the water together, the material thus being prepared for the jigs or other slime-washing machines. The hydraulic classifiers in general use are, with unimportant modifications, forms of the old German *Spitzlutte* or *Spitzkasten*, in which the particles of ore settle in pointed boxes against an upward current of clean water. They are regulated according to the work to be done by varying the velocity of the stream of ore and water passing through them, and the strength of the upward current of water.

The Calumet or Richards-Coggin separator (Fig. 3), which is generally used in the Lake Superior dressing works, consists of four or five boxes, *D*, *D*, etc., or depressions in the bottom of a continuous trough. The water and sand enter at *m* and undergo successive washings in each box until the fine sand overflows at *n*. The operation in each of the boxes is as follows: The heaviest sand at once finds its way to the bottom of the box; the wash-water is brought in through the pipe, *a*, in greater quantity than is sufficient to supply the spigot, *E*. No sand, therefore, can find its way out through *E* that has not weight enough to stem this water stream. This excess of water also acts by keeping the whole bottom of the box in a boil and turmoil, thus ever pushing up the lighter sands and allowing the heavier to keep near the bottom. The shield, *c*, prevents the stream from rising straight up, thereby confining the turmoil to the bottom of the box.

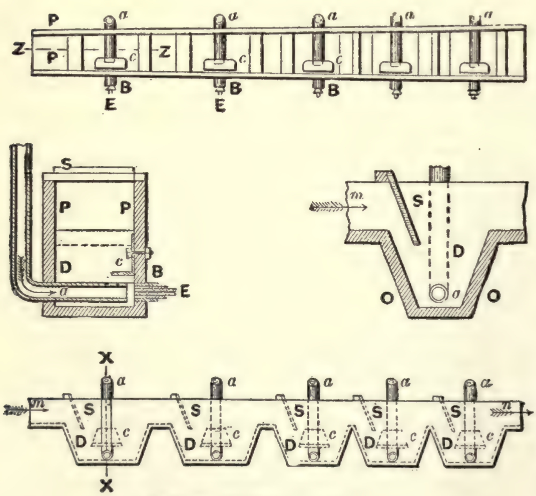


Fig. 3.—Calumet separator.

Jigs.—This is the general name for the concentrating machine universally employed for

separating the particles of mineral and gangue in sand and coarse meal sizes. The Hartz jig (Fig. 4), which, as is well known, consists of a wooden tank with a wedge-shape bottom, divided transversely into a number of compartments, these being further subdivided by a longitudinal partition not extending to the bottom, on one side of which is a sieve, and on the other a piston, remains the standard type of jig, and most of the other jigs in use are but modifications of it. In the Hartz jig the motion of the piston or plunger is given by an adjustable eccentric. The Collom jig, used at Lake Superior, is a side-piston jig (Fig. 5), in which the plunger is depressed by a crank and lever tappet, a spring raising the plunger when the tappet is removed. This device gives a rapid rising current through the jig sieve, and a more gentle descending current, an action which increases the sorting action of the jig. Other mechanical means for securing this slow return movement of the piston have been introduced, but the Collom is the only jig of this type which has come into use in this country. The under-piston jigs have a piston working in a short cylinder placed in the longitudinal portion between two compartments, the piston rod extending out through the jig box through a stuffing-box, and receiving its reciprocating motion from an eccentric. Instead of the ordinary V-shape bottoms, jigs with rounded bottoms are sometimes used, especially as slime jigs, the rounded bottom aiding in the regular movement of the water. For very coarse material, and occasionally for iron ores, instead of giving motion to water through a fixed screen, sieves, either rectangular or circular, having a vertical reciprocating motion in a tub of water, are sometimes used, the effect being the same. Pneumatic jigs have been designed and used experimentally, but have rarely been regularly employed.

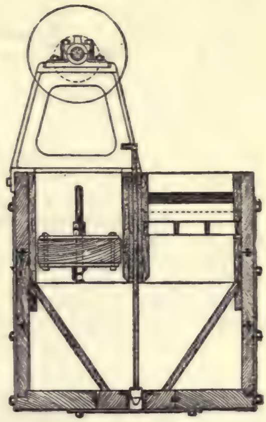


FIG. 4.—Hartz jig.

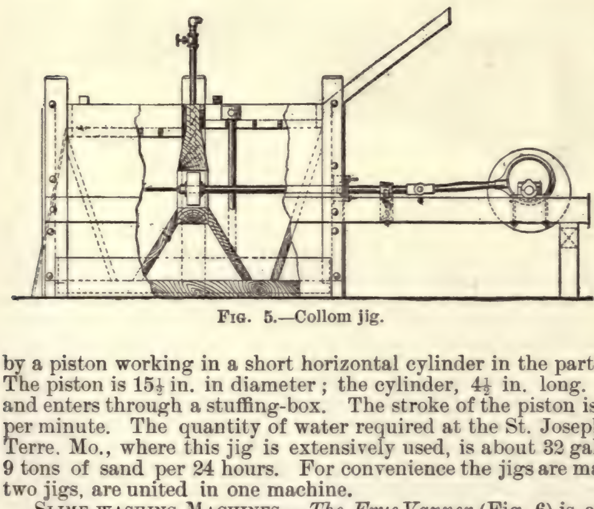


FIG. 5.—Collom jig.

The Argall Jig is a double Hartz jig with a central piston working between two sieves. The reciprocating motion of the piston is given by an adjustable eccentric in the usual manner.

The Parsons Jig is a two-sieve, under-piston jig, each sieve being 22 × 27 in. in the clear. The pulsating movement of the water is given by a piston working in a short horizontal cylinder in the partition between the two jig boxes. The piston is 15½ in. in diameter; the cylinder, 4½ in. long. The piston-rod is horizontal and enters through a stuffing-box. The stroke of the piston is 2 in., and its speed 510 strokes per minute. The quantity of water required at the St. Joseph Lead Co.'s Works, at Bonne Terre, Mo., where this jig is extensively used, is about 32 gallons per minute, jigging about 9 tons of sand per 24 hours. For convenience the jigs are made double—*i.e.*, four sieves, or two jigs, are united in one machine.

SLIME-WASHING MACHINES.—*The Frue Vanner* (Fig. 6) is an endless inclined rubber belt, supported by rollers so as to form a plane inclined rubber surface, 4 ft. wide, 12 ft. long, and bounded on the sides by rubber flanges. The belt travels up the incline and around a lower drum, which dips into a water tank where the mineral is collected. In addition to the travel of the belt, the latter receives a steady shaking or settling motion from a crank shaft along one side, the shake being at right angles to inclination and travel of belt. The best motion is found to be from 180 to 200 strokes per minute, with about 1 in. throw. The ore is fed on in a stream of water about 3 ft. from the head of the belt, and flows slowly down the incline, subjected to the steady shaking motion, which deposits the mineral on the belt. At the head of the belt is a row of water jets. The slow upward travel of the belt, varying from 2 ft. to 12 ft. per minute, brings up the deposited mineral, and the water jets wash back the lighter sand, letting only the heavy mineral pass and deposit in the water tank below. The inclination of the upper surface of the belt varies from ¼ in. to ½ in. in 1 ft. The capacity of the machine is from 5 to 12 tons, according to character of the ore treated, but practice has demonstrated that 6 tons of 40-mesh stuff per 24 hours is as much as it is advisable to treat. A depth of ⅜ in. to ½ in. of sand and water is constantly kept on the belt. The average amount of water required is from 1 to 1½ gallons per minute at the head, and from 1½ to 3 gallons per minute with the pulp.

The Morse-Frue Vanner is a modification of the old type of Frue vanner, the essential difference being in the rubber belt, the surface of the latter being roughened in the new machine, with fine transverse corrugations. The corrugated belt being heavier than the plain

belt, extra supporting rollers on the shaking frame are necessary. The surface of the corrugated belt is given a slightly greater inclination, a fall of from 3 in. to 5 in. in 12 ft. being commonly used, instead of 3 in. to 4 in., as in the case of the plain belt. The water distributor consists of two rows of water-jets, $1\frac{3}{8}$ in. apart, the back ones alternating with the front ones, the distance between the back and front rows being $2\frac{3}{4}$ in. The distributor is placed from 1 in. to 2 in. higher up towards the head of the belt than in the old machines, and is also raised somewhat higher above the belt, so as to give a drop of about $1\frac{3}{8}$ in. from the spouts to the belt surface. More water is required than with the old belts. The revolutions of the crank shaft vary from 194 to 210 per minute, and the forward motion of the belt from 28 ft. to 33 ft. per minute, according to the character of the ore treated. The capacity of this machine is considerably greater than that of the ordinary Frue vanner, and it can be used for the treatment of coarser slimes. Indeed, these belts have given excellent results at some places on material that is usually washed on meal jigs.

The Embrey Concentrator is very similar to the Frue vanner in construction and operation, but the belt is given an end shake instead of a side shake.

The Triumph Table is also a belt machine, resembling the Frue vanner and Embrey concentrator, and, like the latter, the belt has an end shake.

The Lürig Vanner is an end-shake belt machine which is very similar to the Frue vanner in construction, and works upon the same principle.

The Garnier Concentrator is a belt machine, in which the belt is given a peculiar panning

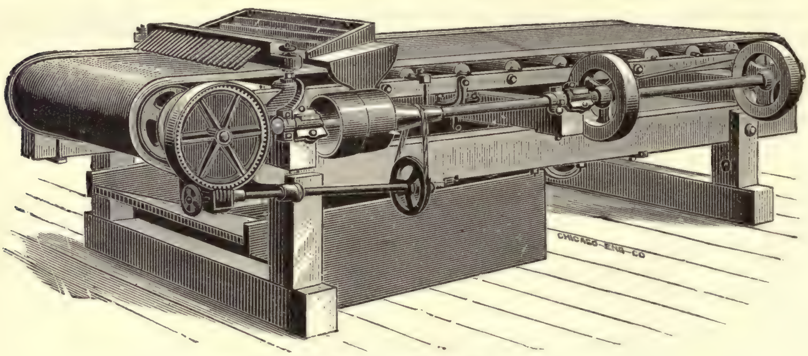


FIG. 6.—Frue vanner.

motion. The belt frame is supported at the rear end on a sliding bearing, and at the front by a vertical eccentric shaft. By means of the eccentric a circular movement is imparted to the forward part of the belt, which becomes approximately a simple back and forth throw at the other end. The belt has a continuous forward movement, as in other machines of this class, and is fed and adjusted in similar manner.

The Woodbury Concentrator is similar to the Frue vanner, but instead of the single smooth belt, thirteen narrow parallel belts are used. The pulp being equally divided between these belts, which prevent it from running to one side of the machine or the other, it is claimed that a thicker bed of pulp can be worked, and that the machine has increased capacity in consequence. A revolving feed-bowl distributes to each belt its exact proportion of sand and water. The rims of the belts are corrugated to prevent cracking as they stretch in passing over the end rollers. The capacity of this machine is claimed to be from 12 to 15 tons per 24 hours. Several of them have been introduced recently, but no actual working results have been published.

The Golden Gate Concentrator consists of a tray about 11 ft. in length, resting upon supports, upon which it has a longitudinally reciprocating movement. This reciprocating movement varies in speed in such manner as to cause the pulp, fed upon the tray at one end, to travel slowly over its surface toward the other end, and the pulp is, by the shaking motion, kept in a loose condition, so that the mineral may settle out of the gangue upon the surface of the tray. The tray proper consists of two distinct parts, forming, however, one continuous surface. One part, being designed for the settling of the mineral, is horizontal, and has hardly any perceptible current of water, thus allowing the fine mineral to settle out of the water and reach the bottom of the tray; the other part has an adjustable inclination upwards from its junction with the horizontal part, and over this part the current of wash-water flows, which washes away the gangue from the mineral. At the junction of the horizontal with the inclined part of the tray, and extending across its width, is a protecting plate, set somewhat above its surface and parallel thereto. Above the protecting plate is an exhaust tube extending across the tray, and connected with two settling chambers, one on either side of the tray, within which a vacuum, sufficient to sustain a column of 4 in. or 5 in. of water, is constantly maintained by an exhaust fan. Just above the protecting plate, and connected with channels formed in the body of the exhaust tube, are exhaust mouths, into which the gangue and water are drawn by the vacuum maintained, being then discharged over each side of the machine into the settling chambers, and thence into the

tailing sluice. The operation of the concentrator is as follows: The crushed ore, with a suitable amount of water, is fed on to the horizontal part of the tray through the distributor at one end of the machine. The shaking motion of the tray causes the pulp to slowly travel toward the protecting plate. The heavy mineral, settling to the bottom, passes under the latter, together with some of the gangue. The larger part of the gangue and all the surplus water pass above the plate, the position of which is adjusted to suit the ore, and, arriving at the exhaust mouths, are drawn off and discharged into the tailings sluice. The pulp which has passed under the plate continues on up the inclined part of the tray, where the gangue is separated from the mineral by a stream of wash-water from the head of the machine. The gangue and wash-water are taken up by the exhaust mouths, as before explained, and the mineral is delivered continuously over the head of the machine.

The Bertenshaw, or *Gilpin County Concentrator* (Fig. 7), is an end bump table, the motion being imparted by a cam at the tailings end. The cam works in a box, which can be filled with tallow or other grease, thus insuring constant lubrication at every revolution of the shaft. In this box is placed a steel shoe, with a bolt through its center for the cam to wear upon, which can be changed end for end as the wear may require. The spring is of torsional character, and easily adjusted, without stopping the machine, by the set-screw and clamp at each end. There is also a clamp bar attached to the center of the spring, which works in the cam box to give the bumping blow when the cam point leaves the shoe. The bed frame of the machine terminates in a solid block of wood at the headings end, against which the table bumps. The table is supported from four standards, swinging on knife-edge bearings. The pitch of the table is adjusted by bolts and set-screws on the front standards. The speed of the machine is governed by the character of the ore to be treated, varying from 130 bumps per minute upward.

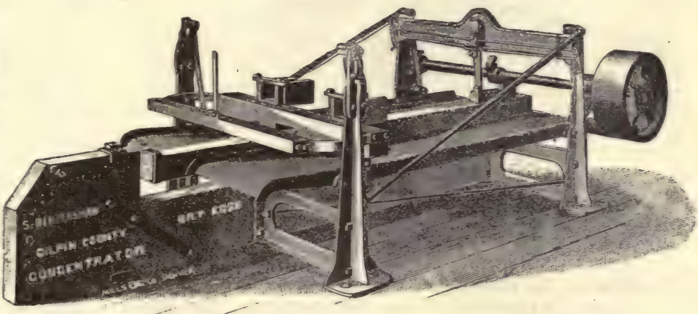


FIG. 7.—Bertenshaw concentrator.

The Rittinger Table, one of the oldest types of slime-washing machines, is much used in Germany, and to some extent in this country. It consists, in the single form, of a plain inclined table, hung from above in such manner as to move freely at right angles to inclination, and operated by a cam and spring, which produce a quick succession of jars and shocks against a solid frame. The ore, in a stream of water, is fed on at one of the upper corners, and flows down the incline, but the successive shocks affect the particles of rock and mineral, tending to jerk them out in the direction of the shock with a force varying with specific gravity and size. The effect of the double force exerted by the downward current of water and jar at right angles thereto is to make the heavier particles take a diagonal course, and, by a few adjustable buttons on the lower end of the table, a separation according to specific gravity is brought about, the heaviest particles moving farther across than the lighter. Along the upper end of table unoccupied by the pulp discharge, water jets flow on the table in regulated quantity, so that its whole surface is washed and the line of the mineral particles controlled. The tables are usually hung in pairs, to save space and machinery. The tables are sometimes of wood, with rubber covering; sometimes of slate, marble, or plate glass, about 4 ft. wide by 8 ft. long, and varying in number and intensity of shocks with the fineness of ore treated. These tables are well adapted for the treatment of the coarser slimes, but their capacity is small.

The Parsons-Rittinger Table is a modification of the old Rittinger side-bump machine. The tables, as used at Bonne Terre, Mo., are built in pairs, and each table is made double, as usual, each half of the double table being about $3 \times 7\frac{1}{2}$ ft. Instead of being hung from rods, the table is supported on four cast-iron feet or guides, which slide on horizontal steel rods. The latter rest in cast-iron saddles, bolted to heavy sill timbers, which run under a whole row of tables. The tables bump against each other, the blow being taken by a joist of hard wood lying loose between them. The tables are forced apart, against the tension of springs, by a spiral, wedge-shaped cam. The number of bumps given per minute is 150; throw, $\frac{5}{8}$ in. The tables are inclined at an angle of $4\frac{1}{2}°$. Their surfaces are covered with black enameled duck, such as is used for desks, which furnishes a covering cheap and easily renewed, and well adapted for the fine material treated at Bonne Terre.

The Evans Table is a circular buddle of improved pattern, which is in general use at the Lake Superior dressing works. Referring to Fig. 8, *A* is a launder to conduct the slimes from the catch-pit or slime box to the distributor, *B*, which has a partition (*a*) in it to separate the clear water from the puddled water or slime water. The clear water is supplied by pipe (*d*) to the distributor, and runs over one-half of the table, *D*, while the slime water

runs over the other half, being controlled by the division piece, *L*. The sand and water being on one side of distributor, *B*, runs through its perforated bottom, and are distributed equally over one-half of the stationary head, *C*, and run on the rotating table, *D*, into the circular launder, *N*, then through the waste pipes, *O O*; the ores remain on the upper part of table, *D*, and after concentration being shielded from the action of clear water by the cone-shaped head, *C*. The proper grades of ores are, through the action of clear water, washed about half way down the rotating table, *D*. They then come in contact with the diagonal perforated pipe, *E*, and are re-washed by a succession of small jets from perforations of small pipe. The ore passing between the jets is carried around on the rotating table, *D*, until it comes in contact with a jet of water from pipe, *F*, and conducting board, *G*. The jet, *F*, conducts the ore into hutch, *H*, through pipe, *I*.

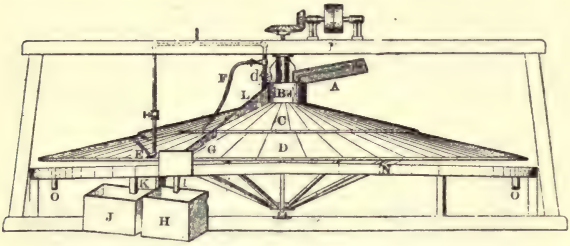


FIG. 8.—Evans table.

The middle or second grade ore is washed off table, *D*, by the perforated pipe, *E*, and is deposited in hutch, *J*, through pipe, *K*, to be re-washed. The head, *C*, is suspended from frame, *M*, so that it can be readily adjusted relatively to the table as it may be required. The arms and segments should be made of hard pine, about half seasoned. The sheeting or surface should be soft pine, and must be green lumber and perfectly clear. The surface of table must be true and uniform, and the width of the boards should not exceed 5 in. The boards are joined by tongue and grooves. The speed of machine is one revolution in 80 seconds. Pitch or incline of table, $1\frac{1}{4}$ in. to 1 ft. Pitch of head, $1\frac{3}{4}$ in. to 1 ft. The capacity of the machine is 25 to 30 tons per day of 24 hours.

The Linkenbach Buddle is a stationary, continuous-working, outward-flow table, designed by C. Linkenbach. The table itself is fixed, but both the supply and receiving launders revolve, the advantages thus gained being cheaper construction and the possibility of using very large tables, requiring small motive force. The principle of the slime washing on this table is the same as with the rotary round table. The slimes are delivered upon a distributing apron at the center, and are discharged at each revolution of the axle, spreading out over the table. The axle carries the perforated wash-water pipes, which extend out over the table, and at each revolution wash the pulp covering the surface of the latter. The headings and tailings are discharged into a circular launder, around the table, which revolves at the same rate as the wash-water pipes. The tables are made of thin iron plates, supported by radial arms, covered with a layer of cement about 3 in. thick. The capacity of a single table, 26 ft. in diameter, is said to be about 15 tons of fine meal and pulp per 24 hours. To economize space, and further cheapen the cost of construction, triple tables are sometimes used, the three being placed one above the other, and the feed-water pipes being carried on the same axis.

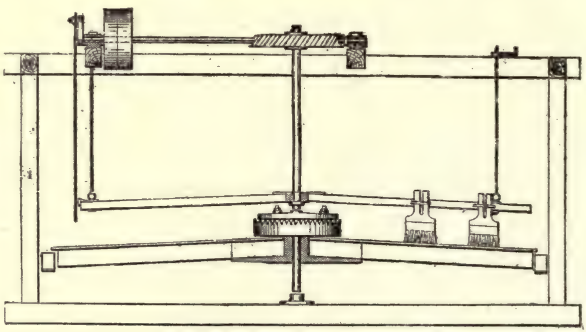


FIG. 9.—Collom buddle.

The Collom Buddle (Fig. 9) is a convex, circular revolving table, over one-half of which, and parallel with its surface, are fixed six light arms, from each of which are suspended two or three small brooms, lightly sweeping the surface of the table. The pulp is fed at the center of the table, and as it spreads out the coarser particles are stirred repeatedly from their positions and caused to roll outward, or toward the tail end of the table.

IRON-ORE DRESSING MACHINERY.—In this country much money, labor, and thought have been devoted to the enrichment of iron ores by roasting to drive off sulphur and carbonic acid, or make the ore more friable, and by washing and screening to remove the clay and sand from earthy ores. Iron ores being so different in character from lead, zinc, and copper ores, their value per ton being so much less, and many varieties being magnetic, a property which is made available in the separation of the mineral from the gangue, iron-ore dressing works, and the machinery used in them, is quite different from that employed for other ores. Earthy, clayey ores are cleaned in many districts by crude machines of large capacity, such as log-washers, which suffice to make a fairly good separation of the mineral and gangue, the difference in specific gravity being so great. Rough jigs are used in many places, and

in some localities elaborately equipped dressing works have been erected. For many years the magnetites of the Adirondack region have been roasted, and jigged on screens in water. Laterally crushers and rolls have been introduced for comminuting the ore, and plunger and rotary jigs have taken the place of the cruder jigs formerly in use. At the large dressing works of the Chateaugay Ore and Iron Co., at Lyon Mountain, N. Y., the cost of dressing 137.551 tons of ore, from September 26, 1886, to January 1, 1888, was 30 7 cents per ton, which was divided as follows: Fuel, $6\frac{1}{4}$ cents; labor, $15\frac{1}{4}$ cents; oil, waste, etc., 1·7 cents; supplies, renewals, and repairs, $7\frac{1}{2}$ cents. The ore was crushed from 15 in. size to $\frac{1}{4}$ in. size by Blake rock breakers and multiple crushers, and was washed on Conkling jigs. Recently much attention has been given to the magnetic concentration of iron ores, and several plants, which have already made large outputs, have been erected. The most extensive and systematic work with this process has probably been done at Witherbee, Sherman & Co.'s mines at Port Henry, N. Y., and at the Croton mines, at Brewster, N. Y. At the latter place, Mr. W. H. Hoffman states that 88 per cent. ore is concentrated at a cost of $1.95 per gross ton of concentrates. This expense is divided as follows: Mining and delivering to roasters, $1.13; roasting, 23 cents; handling at roasters, 3 cents; preparation and screening, 22 cents; supplies and repairs, $5\frac{1}{2}$ cents; separating, including labor and power, 7 cents; delivering concentrates to railway, 4 cents; office and laboratory expenses, $4\frac{1}{2}$ cents; insurance, interest, and taxes, 13 cents. This is equivalent to a cost of less than 16 cents per ton of crude ore for dressing, and is very remarkable, and, at the present time, exceptional practice.

HYDRAULIC MACHINES.—*The McLanahan Improved Double-log Ore Washer* consists of a long, inclined box, in which revolve two parallel logs, studded spirally with broad, flat teeth. The logs are from 17 in. to 18 in. in diameter, hewn hexagonally, and 30 ft. long, covered with iron their entire length. The washer box is placed on an incline of from 2 to

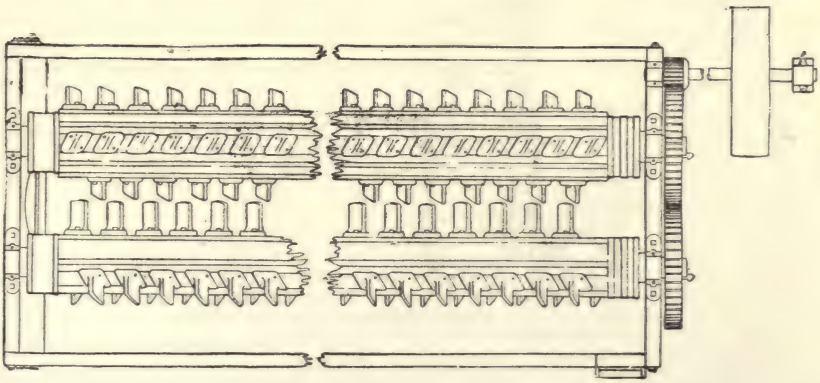


FIG. 10.—Thomas washer.

3 ft. in its length, thus practically submerging the logs one-half their entire length, the back end of the washer box being 4 ft. high. The teeth with which the logs are studded are made with detached bases, the bases being secured to the logs, so that the chilled teeth may be renewed without disturbing the bases. The logs are provided with heavy flanged gudgeons, the back or lower gudgeon being protected with a chilled thimble, which runs in a chilled step or bearing.

The logs are both driven from the front or discharge end by spur and bevel gearing. Two or more washers may be set side by side, all driven by the same main line shaft, with countershafts to each washer, this countershaft being fitted with a shifting clutch, so that any one machine may be readily stopped without interfering with the operation of the others. Sometimes it is desirable to drive from the back end, but in all cases both logs are driven from the same end, and logs are always submerged at back end. The ore to be washed is brought from the mines in tram-cars and discharged directly into the washer-box through a coarse grating, or "grizzly," which prevents very large lumps going into the washer. As the teeth agitate and feed the ore forward toward the discharge, it is met by a stream of water which carries the clay back to the mud discharge. The ore, after being thoroughly separated from the adhering clay and soil, passes into a revolving sand screen, where it receives a final rinsing, and passes clean and bright onto an inclined conveyor, which serves as a table from which any foreign material may be hand-picked as it is slowly carried forward into loading bins, or discharged direct into cars. No ore washer is complete without the revolving screen and conveyor, both of which are of simple construction, made of iron and steel, and especially designed for this work. The screen is driven by gearing from the discharge end. The back end, being carried on friction-roller wheels, admits of large opening to receive the ore from the washer. The conveyor is made of steel pans 24 in. wide, secured to double-link chain of $\frac{1}{2} \times 1\frac{1}{2}$-in. iron, and $1\frac{1}{4}$-in. steel pins, with wearing blocks in joints to protect the links.

The Thomas Washer, which is very similar to the preceding, consists essentially of a

rectangular box having cast-iron ends and heavy oak bottom and sides. The box is usually about 25 ft. long, 5 ft. wide, and 2 ft. deep, having two heavy pieces of timber (see Fig. 10), extending from end to end, and fitted with gudgeons to revolve in suitable bearings in the cast-iron ends of the box. These shafts, or "logs," are provided with a series of blades, or shovels, of cast-iron, arranged helically, in such manner that the logs, which are turned in opposite directions, form two large screws. The main box is set at a small angle from the horizontal, and receives the ore at its lowest end, while a stream of water enters at the upper end. The logs revolve in the ore, and move it, gradually, to the upper end of the box, whence it is discharged, cleaned, through a proper opening, the current of water having washed off the light and worthless gangue. The water and tailings leave the box at the lower end. The angle at which the machine is inclined, and the quantity of water used, depends upon the character of the ore treated. The manufacturers of these machines give the following data: average amount of water required for a 25-ft. double-log washer, 35 to 50 gallons per minute; capacity, 50 to 75 tons of ore per day; power required, 12 to 15 horse-power.

The Conkling Jig consists of a circular sieve, suspended from one end of a lever in a wooden tub 4 ft. 11 in. square and 4 ft. 8 in. deep (inside measurement), being moved up and down by a cam striking the opposite end of the lever. The concentrates pass through the sieve to the bottom of the tub; the tails pass out by means of an annular opening around the jig shaft. The general arrangement of this jig, as used at the works of the Chateaugay Ore and Iron Co., at Lyon Mountain, N. Y., is shown in Fig. 11. The spider is made in one

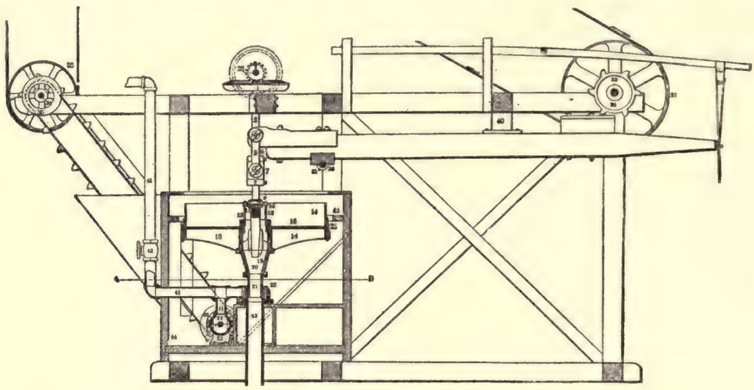


FIG. 11.—Conkling jig.

piece of cast-iron, with a taper bore to receive the jig shaft, which is keyed into it. It is also supported by the standards from the flange, which may be moved by the upper and lower nuts. A sheet-iron hoop, 12 in. high, is bent around the spider, and fastened by the holding-down bands, which are riveted to the rim, pass through the holes in the end of the arms, and are fastened below with nuts. The screen plates rest on the arms of the spider, and are held in place by U-bolts passing under the arms and through the holes in the screens. The screen plates are $\frac{1}{2}$ in. thick, made of cast-iron, in segments of $\frac{1}{6}$ of a circle; the holes are $\frac{5}{16}$ in. in diameter on top, and $\frac{7}{16}$ in. below.

Beneath and bolted to the spider is the cone (*20*); under that is the water sleeve (*21*), which slides up and down in the water box (*22*). All the water which is to be used in jigging passes through these two boxes, and flowing out through the annular openings, keeps the bearings free from grit. The water, under pressure of 8 ft. head, enters through the 3-in. pipe (*41*), provided with a valve (*42*) to regulate the quantity.

The trunnion piece (*7*) is kept in place by the upper and lower collars, which are provided with set-screws. The links (*5*) connect the jig with the lever beam. The jig shaft passes up through the horizontal bevel-gear wheel (*1*) by which it is rotated; the shaft moves freely up and down, but it is provided with splines in which fit keys attached to the gear wheel. The pinion is driven by belt from the rear driving shaft (*33*). The pulleys to transmit the rotary motion are conical, reversed in order to change the speed. The cam wheel (*26*) is provided with 6 cams, and is keyed to the shaft, which is driven by a belt 8 in. wide, passing over the 36-in. driving pulley (*27*). The cam wheel makes 43 revolutions per minute, giving about 260 jars per minute to the jig. The lever beam is set to move the jig up and down about $\frac{5}{8}$ in., giving a slow up and a quick down motion. The jig makes seven revolutions per minute. The practice in dressing iron ores at Lyon Mountain, as described by Mr. F. S. Ruttman, Trans. Am. Inst. Mining Engrs., vol. xvi. 609, is as follows: The crushed ore is brought from the hoppers to the jigs by chutes provided with gates at the lower end, just above the screen plates. The screens are first covered closely with pieces of heavy ore about the size of hickory-nuts; the crushed ore is then spread over this until it is level with the collar of the spider, about $2\frac{1}{2}$ in. to 3 in. deep. The spring pole is connected with the lever beam by the strap, the water turned on, and the jig started.

The water flows upward through the screen plates and over the collar of the spider, carrying the gangue to the tail race ; the ore settles through the screen, is collected at the bottom of the tub, and thence raised by the elevators to bins. The rotation of the jig produces an equal distribution of the crushed ore on the screen plates, and also forces the particles to traverse a path longer than the radius of the sieve. The crushed ore is allowed to fall on the screen as near the outer periphery as possible. The jig has a capacity of treating 5 tons of ore per hour, requiring 135 gallons of water per minute, or 1,620 gallons per ton treated. One man or boy is sufficient to attend to two jigs.

The McLanahan Improved Jig, operating on the same principle as the common Hartz jig, is a rough jig designed for dressing iron ores. They are built in sets of four, in tanks 18 ft. long, 14 ft. wide, and 12 ft. deep. The framework of the tank extends to sufficient height to carry the sizing trommel and the elevators, the total height being 24 ft. The tank is divided into four jig compartments, besides an elevator pit at each end. The pulsating movement of the water in each jig compartment is effected by a central piston working in a cylinder. The stroke of the piston is adjusted by an eccentric, as in Hartz jigs. The trommel above the tank is divided into four sections, each being covered with a screen of the proper size to suit the ore being washed. The jigs are fed by spouts from the various sections of the trommel. The jigs discharge concentrates continuously into a launder leading to the elevator pit at one end of the tank, by which they are raised to storage bins for shipment. Tailings are conveyed to the elevator at the other end of the tank, by which they are raised and loaded into cars to be carried to the waste dump. The water in these jigs is used over and over again, with a small loss.

MAGNETIC SEPARATORS.—*The Buchanan Magnetic Separator* (Fig. 12) consists of two iron rolls, journaled in two horseshoe magnets. These magnets are wound with insulated copper wire and excited by a dynamo. The direction of the winding is such that one roll is of north and the other of south polarity, thus forming a powerful magnetic field between the two. The ore is fed into hoppers above the rolls, and the stream of ore from them is regulated by hand levers. As the ore is drawn into the magnetic field between the rolls, all that is magnetic is attached to the faces of the rolls and carried around to the opposite sides, where the rolls are non-magnetic, and dropped. The gangue being non-magnetic, falls directly between the rolls. One of the rolls is movabie, so that the distance between them, and consequently the strength of the magnetite field, may be adjusted. An interesting comparison between this machine and hydraulic jigs was made at the Croton mines at Brewster, N. Y., where the ore, a dense magnetite, was crushed by Cornish rolls so as to pass a 16-mesh screen. Ore assaying 37·968 per cent. iron, and 29·30 per cent. silica, gave concentrates, with the Buchanan separator, assaying 64·554 per cent. iron, and 5·350 per cent. silica. A few years before the introduction of the magnetic machine, plunger jigs had been used, when the following results were obtained : Fine jigs, crude ore assayed 36·48 per cent. iron ; concentrates, 65·56 per cent. iron ; tailings, 14·31 per cent. iron. Coarse jigs, crude ore, 36·48 per cent. iron ; concentrates 58·78 per cent. iron, and tailings, 22·16 per cent. iron.

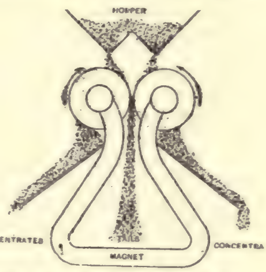


Fig. 12.—Magnetic separator.

The Ball-Norton Electro-magnetic Separator, sometimes called the "Monarch," consists of a partially closed chest, having an opening at *f*, Fig. 13, from the feed hopper, *h*, through which the ore is delivered to the machine from a storage bin, provided with means for regulating the flow of ore. Other openings are provided for the discharge, at *t*, of tailings ; at *m*, of middlings ; and at *c*, of concentrates ; also at *e* for allowing free ingress of air to the chest at that point, and at *s*, where a powerful exhaust fan is connected. The openings at *t* and *m* are kept sealed against ingress of air at those points by means of hinged and weighted valves, *v v*, which discharge the products from the hoppers, *p* and *k*, continuously, and in the same proportion as received from above, when a sufficient weight has accumulated upon the inside to cause the contents of the hoppers to leak by the valves. The machine is also provided with two drums, *1* and *2*, turning upon the shafts, *i* and *j*. These shafts, together with the magnets, *a* and *b*, which they also serve to support, stand still, while the drums may be rapidly revolved around the magnets and out of contact therewith. It will

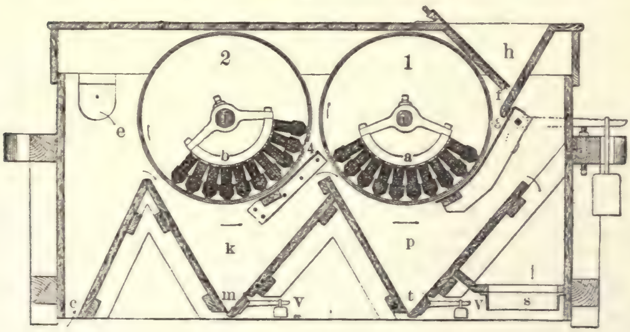


FIG. 13.—Ball-Norton magnetic separator.

be noticed that the magnet occupies a sector of the drum, the proportions being such that, approximately, one-third of the periphery of the drum is within the influence of the magnetic field, while the upper two-thirds is outside of the field and removed from the magnetic influence. The magnet is so constructed as to present a series of poles of alternately opposite polarity near the inner surface of the drum. In accordance with the well-known phenomena of magnetic attraction, which in the case of powerful magnets is exerted at a considerable distance from the magnetic poles, any magnetizable matter brought near the outer surface of the drum, within the arc covered by the magnet, will be powerfully attracted and drawn into firm contact with the outer surface of the drum. These drums are composed of a non-metallic and neutral material, such as wood, paper, etc., and they turn in the direction indicated by the arrows near the top of the drums. Just below the feed hopper, an apron of neutral metal, *3*, is arranged, curving downward and forward in the direction of the rotation of the drum, its lower portion describing a short arc concentric to the surface of the drum. This serves as a chute to direct the stream of ore falling from the feed hopper within the influence of the first two or three poles of the magnet. A similar but somewhat shorter apron, *4*, is arranged in like relation to the second drum and magnet, *b*.

In operation the magnets are excited, the drums revolved in the direction indicated, and the air current established through the machine in a direction opposite to that of the drums. The ore passing down the chute under the first drum, the magnetizable portions are drawn into contact with the drum, and take on the forward movement of the latter. When the ore reaches the limit of the arc covered by the magnetic field it is no longer attracted, and takes on a tangential movement, which carries it away from the drum. It has now, however, passed the edge of the second apron, and, on leaving the first drum, comes within the influence of the magnet of the second drum, where similar operations are repeated, a portion being finally discharged as concentrate at *c*. The function of the second drum and magnet being to differentiate the product from the first drum into two portions, which may be conveniently designated as middlings, discharged at *m*, and concentrates, discharged at *c*. The easy working capacity of a machine having drums of 24 in. diameter and 24 in. working face is said to be from 15 to 20 tons per hour of ore granulated to pass 16 to 20-mesh screens. The power required is from 1 to 1½ horse-power in electricity for each drum, and ½ to ¾ horse-power to drive the machine. Mr. C. M. Ball states that Port Henry "Old Bed" ore has been converted by means of this machine into a Bessemer ore, carrying iron, 71·10; phosphorus, 0.037. This concentration was made from the crude ore, carrying iron, 58·7; phosphorus, 2·25; the Bessemer concentrate representing about 65 per cent. of the original mass. See Trans. Am. Inst. Mining Engrs., vol. xix. p. 187.

The Wenström Magnetic Separator (Fig. 14) has a stationary field magnet, and an armature barrel consisting of a number of soft-iron bars, separated from one another by a non-magnetic material—strips of wood, for instance. The whole is bound together by non-magnetic end rings. The bars are cut away alternately on the inside, to make one bar project only toward the north poles of the magnet, and the next only to the south poles. This gives each succeeding bar opposite magnetism. On each of the four sections of the magnet are wound 15 lbs. of copper wire. An Edison dynamo furnishes a current of 10 amperes and 33 volts. The ore is fed to the barrel by means of a hopper, as shown in outline, Fig. 14, the cylinder turning in the direction of the arrow. The magnetite adheres to the bars of the barrel and is carried downward past the first delivery chute. Below the machine, the bars, departing from the influence of the electro-magnet, which is placed eccentrically, lose their power to hold the particles of magnetic iron ore, and they drop off. The particles of rock in the ore, being non-magnetic, drop from the barrel almost immediately and fall on the first chute shown in the engraving.

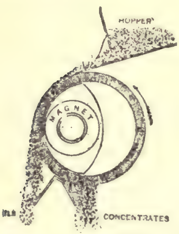


FIG. 14.—Wenström magnetic separator.

The Edison Unipolar Non-contact Electric Separator (Fig. 15) differs from other magnetic separators in that it has no moving parts, except such as are essential for adjustment of the apparatus in treating different ores. The separator consists simply of a hopper, a magnet, and a partition to separate the concentrates and tailings into different receptacles. The illustration shows but one hopper, but in practice the ore can pass on each side of the magnet, thus doubling the capacity. The ore, after being properly crushed and sized, is placed in hoppers, from which its discharge is controlled by bars closing slots which extend the length of the hopper. These slots are made adjustable, so as to suit the size to which the ore has been reduced. The hoppers are adjusted to appropriate heights above the magnet. The magnet is a mass of soft iron, 6 ft. long by 30 in. wide and 10 in. thick, weighing 3,400 lbs., and wound with 450 lbs. of copper wire, the coil being connected with a dynamo consuming 2½ horse-power, and requir-

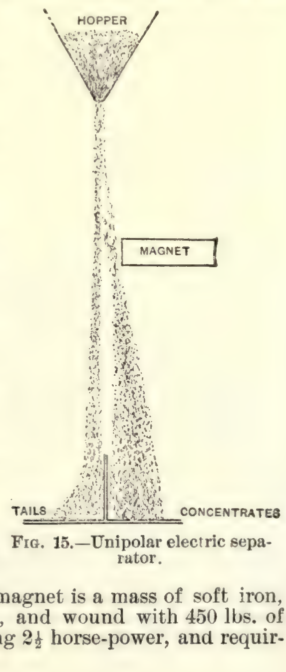


FIG. 15.—Unipolar electric separator.

ing a current of electricity of 16 amperes, and an electro-motive force of 116.5 volts. The material falling from the hopper passes the face of the magnet, but does not touch it. The distance of the magnet from the vertical plane of the falling material is so chosen that its attraction causes the magnetic to separate from the non-magnetic particles sufficiently to alter their direction. By reason of the force of gravity, this deflection of the trajectory, while sufficient to draw the magnetic particles away from the non-magnetic, does not draw them against the magnet, but should any ore accumulate on the magnet, it can be instantly dropped by breaking the current. The exact distance, however, is maintained so that none can stick to the magnet. Owing to the altered trajectory, the magnetic ore falls upon one side of the partition, which is so adjusted as to secure the best result, while the gangue material drops upon the opposite side. The capacity of a machine of this kind, of the size given above, is said to be easily 150 tons per day of ore crushed so as to pass a 10-mesh screen, or 300 tons per day for a double-face machine.

The Conkling Magnetic Separator is a belt machine of the general form indicated in Fig. 16, which merely shows the principle and not the detail. The ore is fed on a belt, and carried along under a series of belts running at right angles to the first. These cross belts pass between the magnets and the ore lying on the distributing belt, and may be placed at varying distances from the latter. As the ore, reduced to the proper size, passes along on the distributing belt, the magnetic belts, which may be influenced by magnets of different powers, pick up and carry to one side the magnetic particles of the ore, while the non-magnetic portion of the gangue is carried off as tailings.

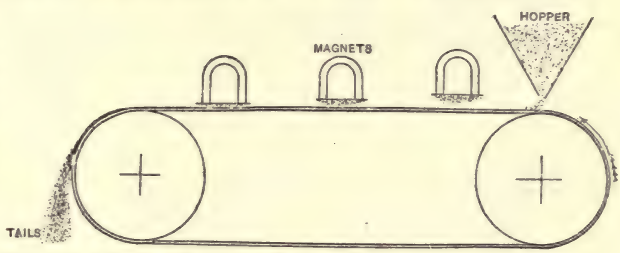


Fig. 16.—Conkling magnetic separator.

The Hoffman Magnetic Separator consists of an endless belt traveling over two drums, within one of which is fixed a series of magnets, which occupy a sector of the drum, so arranged that rather more than one-half of the latter is under magnetic influence. Between the two drums, and immediately below the upper surface of the belt, is another series of magnets, called the stratifying magnets. The ore is fed on the belt from a hopper, which has a device for insuring an equal distribution of the ore across the surface of the belt. The ore is carried forward by the travel of the belt, passes over the stratifying magnets and over the magnets within the drum. As the belt turns over the latter, the non-magnetic material falls off into a bin, while the magnetic particles are retained until the belt passes out of the magnetic field, when they are dropped into a separate bin.

The Lovett-Finney Magnetic Separator consists of a shaft on which are placed two 30-in. iron disks 50 in. apart. The space between the disks is wound with No. 14 insulated copper wire, forming a solenoid. One end of the shaft is hollow, and through this central aperture are passed the ends of the wire, which connect with the commutator attached to the shaft. From the rim of each disk extend, alternately, a number of iron bars, each bar extending almost to the edge of the opposite disk, but insulated from this, as well as from the adjacent bars. The spaces between the bars are filled with non-conducting cement, giving to the finished wheel the shape of a solid cylinder, 30 in. in diameter and 50 in. long. Over this cylinder travels an endless belt of ordinary canvas, held tight by an adjustable pulley. An apron of copper is placed under the magnetic wheel, closely following the curvature of the same. Over the apron the crushed ore is carried by a liberal flow of water. An electric current of 13½ amperes and 110 volts is run through the wire of the wheel, which is revolved at the speed of 14 revolutions per minute. The disks and bars being thus magnetized, the magnetic particles of ore are attracted to the wheel, and attach themselves to the endless belt. The non-magnetic particles are in the meantime washed off and carried away by the water. When the belt leaves the top of the magnetic wheel it carries with it the collected concentrates, which are shed into a water tank, through which the belt passes before returning to the separator. From this tank the concentrates are lifted by a flight conveyor and deposited directly on the railroad car, ready for shipment. The advantage claimed for this separator is the entire absence of dust, and the wear on the machinery due to the same. According to Mr. Axel Sahlin, a machine at Weldon, N. J., has been in constant operation for nine months, handling about 120 tons of crude ore per day, and the only repairs have been one new canvas belt, costing $5, and one course of new wire cloth for the revolving screen, costing about $20. The dynamo furnishing the current for this machine required 3 horse-power.

Works for Reference.—The Art of Ore-dressing in Europe, by W. B. Kunhardt, 1889 ; *Losses in Gold Amalgamation, with Notes on the Concentration of Gold and Silver Ores*, by McDermott and Duffield, 1890 ; *Mining and Ore-dressing Machinery*, by C. J. W. Lock, 1890 ; *Aufbereitung der Erze*, by C. Linkenbach ; "Description of Lauremburg Dressing Works," *Berg und Huettenmannische Zeitung*, 1882, xli. 140–144 ; "Description of Clausthal Dressing Works," *ibid* , 1882, xli. 29, *et seq.* ; "The English *vs.* Continental System of Jigging," by H. S. Munroe, Trans. Am. Inst. Mining Engrs., xvii. 637 ; "The New Dressing

Works of the St. Joseph Lead Co.," by H. S. Munroe, *ibid.*, xvii. 659; "Velocity of Bodies of Different Specific Gravity falling in Water," by R. H. Richards and A. E. Woodward, *ibid.*, xviii. 614; *The Metallurgy of Silver*, by Manuel Eissler, 1889.

For further details concerning the magnetic concentration of iron ores, see Trans. Am. Inst. Mining Engrs., vols. xviii. and xix., which contain numerous papers upon the subject.

ORE SAMPLING. Gold and silver ores are generally bought and sold by sample. In Colorado, where nearly all the silver lead ores, and much of the gold ore, is sold to public lead smelters for reduction, this custom is followed exclusively, and the methods of ore sampling have undoubtedly been carried to a higher degree of perfection there than anywhere else in this country. Attached to each smelting works is a sampling mill, in which the samples are prepared. The usual arrangement of these sampling mills, and the method of sampling, are as follows: The ore, having been unloaded from the wagons or railway cars, is taken to the mill, where the lumps are crushed to uniform size, say 1 in., by means of a Blake, Krom, Dodge, or some other coarse-crushing machine. The broken ore falls to the floor below the crusher, whence it is shoveled into barrows and wheeled away to bins in the roasting-furnace house or blast-furnace house, as the case may be, with the exception of every tenth shovelful, say, which is thrown to one side, forming a separate pile in the sampling mill. With ores of average grade it is customary to throw aside every tenth shovelful, but with richer ores, every fifth, or even every third, shovelful is rejected. The sample, constituting one-third, one-fifth, or one-tenth of the original lot, is then wheeled to the sampling floor, which is covered by a smooth iron plate, and quartering is commenced. A paragraph from a paper read by Dr. R. W. Raymond before the American Institute of Mining Engineers, June, 1891, describes the method of quartering a sample as practiced at the leading sampling works of the West at the present time:

"The mass is first shoveled into a ring on the sampling floor, and this ring is then shoveled toward the center, each shovelful being carefully delivered upon the summit of the pile in the center, so that they shall roll equally in all directions. A conical heap having thus been formed, it is pulled down and spread out. The workmen walk round and round the pile, pulling with the shovel, as it were, the ore toward them, so that it rolls outward. The lower six inches of the pile is not disturbed, and when this process is finished, the conical heap has become a truncated cone of larger base area and 6 in. high. This flat heap is now quartered by pressing a stick or a board held edgewise down into it so as to mark the diametrical divisions. Two opposite quarters are cut out with the shovel and removed. The other two are again mixed, formed into a conical heap, and flattened out as before. This procedure is repeated until the quantity has been reduced to one or two wheelbarrow loads, when, if the material has never been mechanically crushed, it is crushed in the rolls to, say, half-inch maximum size. The quartering is then continued till the sample has been reduced to a panful. This is ground, say, to 50-mesh size (after a partial preliminary drying, if necessary, to facilitate the grinding in a rotary fine-crusher), and then taken to the assay laboratory, where it is thoroughly dried (say, for twenty-four hours at 212° F.), and rubbed fine until the whole will pass through an 80-mesh sieve. Quartering is then resumed and continued until the sample is only sufficient to fill three bottles, one of which is for the assay of the works, one for the customer, and the third for the umpire assay, if such should be required."

In some sampling works automatic samplers are used, in which case the original sample (say, one-fifth or one-tenth of a gross lot) is crushed by rolls to a convenient size, say so as to pass a 4-mesh sieve, and the crushed ore is raised by a belt elevator to the top of the mill, where it goes through a drum screen, the ore which is rejected being returned to the rolls. The ore which has been crushed to proper size and passes the screen falls through a tube or spout in which it is divided mechanically. The means employed for this all depend upon the same general principle of cutting or diverting the falling stream of ore by means of flanges, fingers, or traveling buckets, in such manner as to obtain any desired proportion of it for a sample. There are numerous automatic samplers in use, but most of them are constructed upon this principle.

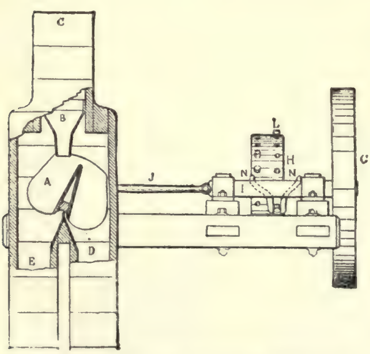


Fig. 1.—Brunton's automatic sampler.

Brunton's Automatic Sampler (Fig. 1), which is one of the best in use, is designed upon a slightly different principle from the others, in that the entire ore-stream is deflected to right or left. This is accomplished by placing a funnel with a large opening at a certain point in the spout. Just below the bottom of the funnel is a diaphragm or switch, the bottom of which is pivoted midway in the spout. The ore falling against this is diverted to one side or the other according as the diaphragm is turned. Outside of the spout the diaphragm is connected with a suitable gear, whereby it can be deflected at any desired interval, say five seconds in twenty-five, or five seconds in fifty, during which time all the ore passing through the spout is discharged into the sample bin. The first sample is then crushed and elevated, and again reduced by dropping through another spout equipped with a sampler of the same design. The two machines are driven at different speeds to prevent any possible error that

might result from isochronal motion. Experience has shown that 10 per cent. of 20 per cent., or 2 per cent. of the original amount of ore, is usually quite sufficient for the final sample, though in exceptional cases 15 per cent. of 30 per cent., or 4½ per cent. of the whole, are taken. Careful tests of this machine in resampling lots of ore have shown a limit of error of less than one-fourth of 1 per cent. For further details see Trans. Am. Inst. Mining Engrs., vol. xiii. p. 639.

Another device to facilitate sampling is the split shovel, which is an ordinary shovel so divided that in being pushed through a lot of finely crushed ore, a certain proportion only, say one-fourth, is taken. Brunton's shovel, Fig. 2, is one of the best of these. This tool, which is described in the *Engineering and Mining Journal*, vol. li. 718, consists essentially of a flat-bottomed, well-balanced steel shovel, 10 in. in width, having vertical sides, and two

FIG. 2.—Brunton's sampling shovel.

central partitions, 2½ in. apart, thus dividing the shovel into three compartments, the center one being closed by a curved back, and having a width one-quarter of the whole. The operator pushes the shovel into a pile of finely crushed ore. As he raises the shovel, it is drawn back with a sharp rotary motion to the right, which throws the ore contained in the outside compartments out from the back end of the shovel into a rejected ore pile. When the necessary throw to accomplish this result has been given, the motion is reversed, and the shovel brought rapidly to the left, which action discharges the sample from the central compartment of the shovel upon another pile.

While the required motions are somewhat difficult, and beginners are awkward at first, a few weeks' practice brings the necessary skill to enable the operator to sample a pile of ore almost as rapidly as it can be shoveled over. Tests at sampling works and different smelters upon hundreds of lots of ore, many of them in duplicate and triplicate, show that there is no difference between the results obtained by this method and by Cornish quartering in the common manner. Experienced operators attain great rapidity in this method of quartering; in some recent speed tests it was found that a ton of ore could be cut down to a 100-lb. grinder sample by a man in 15 minutes.

In dry-crushing silver mills, where it is desired to take regular and continuous samples, a mechanical arrangement can be fitted to a trough or chute through which the finely crushed ore is passing, which will take a small portion of the pulp at regular intervals. McDermott's and Collom's automatic samplers are machines devised for this purpose.

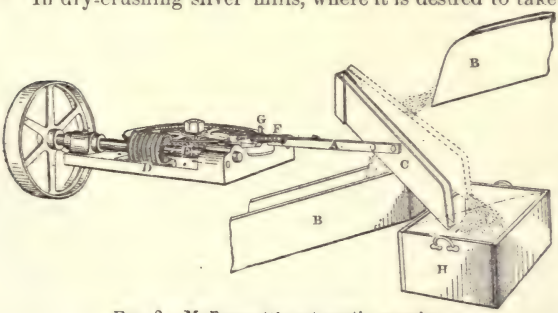


FIG. 3.—McDermott's automatic sampler.

McDermott's Automatic Sampler, Fig. 3, consists of a spout, *C*, which, by means of the worm-wheel, *D*, and the pin, *G*, coming in contact with the lever, *A*, is moved into the stream of ore pulp, causing a small portion of the current to be directed for an instant into the sample box, *H*; the pin, *G*, having then passed the lever, it returns to original position by spring, *F*. This arrangement of long-armed lever, *A*, with spring return enables the slow revolving wheel, *D*, not to take samples too frequently, nor too large; so that the machine can run all day and not take too bulky a sample for convenient handling. The dividing launder splits up the stream of pulp in a large mill for the same purpose, viz.: to keep sample small, by passing sample spout, *C*, through only a part of the stream. This machine can be adapted to mills in operation, where "fall" is limited,

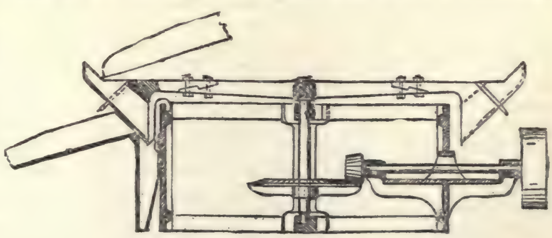


FIG. 4.—Collom's automatic sampler.

either by making a few inches drop at some point in the main launder, which carries the pulp or tailings, or, if this is not practicable, by using a long dividing launder, *B B*, which, being narrow and of metal, will clean itself with less fall than the main wooden launder. The frequency of the samples can be indefinitely increased by adding pins to the gear-wheel, *D*, or increasing the speed of the worm shaft, *E*. The size of each sample taken can be varied by the widths of the dividing launders and of the sampling spout, *C;* these being of thin sheet-iron, can be bent by hand to the desired width.

Collom's Automatic Sampler, Fig. 4, is constructed upon the same principle as the McDermott, but the sample spout is fixed to the end of a horizontal arm, which is revolved slowly by means of a bevel gear, cutting a sample of the falling ore each time it passes through it.

Bridgeman's Automatic Sampling Machine is a new device, designed to give practically finished samples. It is a rotary machine, which takes the whole stream of ore for part of the time, and which, in a single passage of the material through it, gives two or more absolutely independent samples, and cuts down each of these a sufficient number of times to give the smallest final samples desirable without re-crushing. The accompanying illustration (Fig. 5) shows the apparatus in sectional elevation. Extending vertically from the base is a shaft, *A*, provided with a bevel-gear wheel, *B*. Loosely surrounding this shaft is an independent rotary sleeve, *C*, provided with another bevel wheel, *D;* and loosely surrounding the sleeve, *C*, is another sleeve, *E*, which in turn has a bevel wheel, *F*. Means are provided for giving motion to the three bevel wheels, *B*, *D*, and *F*. Fixed to the sleeve, *E*, is a rotary apportioning device, *G*, directly above which is a similar apportioning device, *H*, fixed to the sleeve, *C*. Upon the shaft, *A*, and above the apportioning device, *H*, is still another apportioning device, *I*. The guide chutes, *J*, are annular at their upper portions, and are separated by partitions, *K*, shallow at one side of the machine, deepening toward the opposite side. The apportioning devices, *G* and *H*, are similar in their construction; they are funnel-shaped throughout the greater part of their area, and terminate at the bottom in an annular spout, *L*. At opposite sides of the spout, *L*, and in a direct radial line with each other, are two sets of bottomless compartments, *M*, *N*, divided by partitions from one another and from the spout, *L*. The apportioning device, *I*, comprises an annular trough, *O*, divided preferably into eight hopper-like compartments terminating in outlets, *P*, directly over chutes, *M*, and being provided with adjustable spouts, *Q*, which may be turned to discharge into the spouts, *L*, or paths of the chutes, *M* and *N*. *R* is a hopper into which the crushed ore is fed, and whence, by the action of the spiral blade, *S*, it is discharged in a uniform stream through the spout, *T*, into the rotating trough, *O*, so that one-eighth part of the mass will pass out at each spout, *Q*. By a certain adjustment of the spouts, *Q*, six-eighths of the entire mass passing down will fall into the annular spout, *L*, and be discharged at the inner spout of guide chutes, *J*. One-eighth portion of the mass passing down through the spout, *Q*, which extends over the annular path of the chute, *M*, is distributed equally over the said path, one-eighth part of the said eight portions into each of the distributing chutes, *M*, and the remaining six-eighths thereof into the confluent chutes, *U*, whence it passes with the first discarded six-eighths down through the spouts, *L*, to the chute. The mass is again divided by passing into the apportioning device, *G*, and two approximately equal samples of the mass are obtained in the guide chutes, *J*. The machine is adjustable to give samples of different size. Its capacity is from 15 to 25 tons per hour, and it is claimed that it will sample satisfactorily material of any character; ore with over 10 per cent. moisture even offering no difficulty. It takes feed directly from crusher or rolls, regularly or irregularly, and requires no attention except for cleaning out and removal of samples. Prior to the introduction of this machine at the Blue Island Copper Works, states Mr. Bridgeman, 54 car-load lots (of about 30,000 lbs. each) of copper matte had been treated, on which duplicate samples were made by hand. The average assay contents of these 54 lots were: 7·88 oz. gold, 168·71 oz. silver, 55·24 per cent. copper. The average differences between the two samples of each lot were 0·43 oz. gold, 3·77 oz. silver, 0·71 per cent. copper. Since the introduction of the machine, 22 lots of ore and 138 lots of matte have been run, the latter being of the same general character as the hand-sampled matte, except that it did not, as a rule, carry so much "metallics." By reason of these "metallics," much of this matte was very difficult to sample accurately, as will be easily understood. The weights of these 160 lots varied from 65 lbs. to 42,000 lbs., averaging not less than 30,000 lbs. Their average assay contents were 0·71 oz. gold, 112·04 oz. silver, 51·75 per cent. copper. The average differences between the two samples of each lot were 0·02 oz. gold, 1·19 oz. silver, 0·23 per cent. copper. Reduced to percent-

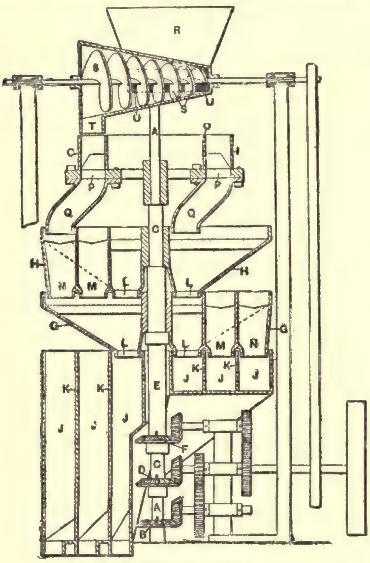


FIG. 5.—Bridgeman's sampler.

ages for the sake of comparison, the average differences were as follows : 54 hand samples —gold, 5·46 ; silver, 2·24 ; copper, 1·29. 160 machine samples—gold, 2·82 ; silver, 1·06 ; copper, 0·45.

Bridgeman's Small Ore-sampling Machine (Fig. 6) is a modification of the large machine. Its particular field of usefulness is the quick and certain cutting down of the miscellaneous small samples (from 5 lbs. to 500 lbs. in weight) that are constantly being received by assay offices. It will handle anything from the finest assay pulp to crushed material of ¼ in. or more in size. In operation, the material is fed either by hand or (with large lots) from a suitably supported bucket into the funnel, *F*, the divider, *D*, being first set in rotation by hand, clockwork, or any convenient power. The divider gives, as will be seen by inspection of the drawing, eight cuts to the revolution, four being delivered to the funnel, *1*, and four to the receptacle, *2*; that is, with uniform flow and speed, cutting the material in half. The divider may easily run 100 revolutions per minute, giving in that time 800 cuts, a very much greater distribution and division than can be secured in any other way. The rejected sample passes down the outlet to *O 2*, into any suitable vessel. The retained portion, should it be too large, may be cut again and again, until of suitable size. The operation is very accurate and rapid ; about as fast as the material will flow through a 1-in. spout.

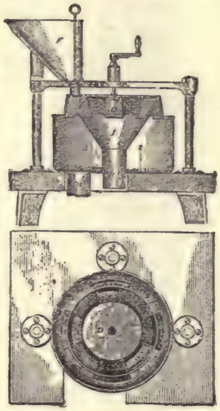


Fig. 6.—Bridgeman's sampler.

Bridgeman's Mixer and Divider (Fig. 7) for ore samples is an apparatus designed to obviate the tedious and frequently inaccurate methods—usually with oil-cloth and spatula—in general use, for mixing and dividing the ground samples of ore, matte, slag, and other similar material. The operation is as follows : The ground material is introduced into the large covered funnel (mixer), the outlet being first closed by thumb or finger, as may be most convenient. Funnel and contents are then well shaken for a few minutes, and then, with opened outlet, passed to and fro over the set of distributing funnels (divider) and bottles, as shown. With very finely ground, or very light material, the flow may be assisted by a slight shaking or tapping with the hand. The little skill necessary is readily acquired. To test the efficiency of the mixer, Mr. H. L. Bridgeman took a mixture of 6 assay tons of litharge, 3 assay tons of soda, and ¾ assay ton of argols ; it was well shaken, divided by weight into three lots, of 3¼ assay tons each, and these charges fused separately in crucibles. The resulting lead buttons weighed 53·436 gms., 53·416 gms., and 53·398 gms., respectively.

Fig. 7.—Mixer and divider.

The Hanley Ore Sampler.—This machine differs radically from others, as it combines the features of both the time-dividing and the stream-dividing types of ore samplers ; and, again, as it furnishes two samples, each serving as a check on the accuracy of the other. The ore, previously crushed by rolls or crushers, or both, is fed through a revolving screen, or may be conveyed directly, to a large hopper, in which there is an oscillating wing, driven by an eccentric rod deriving its motion from a shaft, on which are centered other eccentrics performing the same operation at a later stage of the sampling. This oscillating wing in its passage cuts the stream into two portions, one of which passes directly to the floor, and the other is cut in its descent by a second oscillating wing into two portions again, passing into separate compartments. This operation can be extended in a properly constructed machine until as small a sample as one-sixteenth of the original amount is arrived at, and this divided into two portions, which are crushed fine and again quartered in samples fit for the grinding plate. Each is assayed separately, and they are said to agree within extremely close limits.

Cost of Sampling.—This depends, like any other metallurgical or industrial operation, largely upon local conditions as to the cost of power and labor. In an average Western mining camp, in a sampling mill handling 2,000 tons a month, the following laborers would be required : One foreman, at $5 a day; one assayer, at $4 ; one engineer, at $3.50 ; ten wheelers, at $3, and two quarterers at $3, or a total of $48.50 for labor. One cord of wood for $5 would be consumed, and other expenses, such as bottles, assay supplies, etc., would amount to $5 additional ; depreciation, estimating the plant to cost $5,000, would amount to $2 50 a day, making a total expense of $61, or $1,830 a month—an average of $915 per ton ; thus leaving but a small margin of profit in hand-sampling proper. The profits are usually derived from the sampler's connection with the ore buyers and smelting works, having reduced rates for reduction, as well as tariff arrangements with the railroads, enabling them to purchase ores to great advantage. In many cases they act as agents for the smelting works on commission.

The greater portion of the sampling works in the United States are in Colorado, where the railroad facilities are admirable. There is hardly a mining camp in the State which does not contain one, while in California there are but two, in Nevada but one, three in Idaho, six in Montana, five in Utah, and a few in New Mexico and Arizona.

Oven, Coke : see Coke Ovens.

PACKING. *Corrugated Copper Gaskets,* shown in Fig. 1, are now used for packing pipe joints. They are made of thin sheet-copper, stamped with concentric corrugations, which on compression flatten out and produce a complete metal union. They are not impaired by heat or cold, and can not blow out. From 3 to 6 corrugations inside the bolt circle is ample to insure a permanent joint. They are made in any desired shape. Many varieties of packings for joints are now in the market, made of paper, rubber, cotton, asbestos, graphite, or combinations of these and other materials. Some of these are of compositions which are kept trade secrets, and they are known in the market by arbitrary names, such as Vulcanized Fibre, Vulcabeston, Usudurian, etc., or by the names of the makers, as Jenkins' Packing, etc.

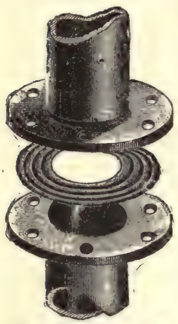


Fig. 1.—Copper gaskets.

Tripp's Metallic Packing is shown in Figs. 2 and 3. It consists of matched sections, which are held against the rod by circular springs which grasp the sections. In Fig. 2 the light color shows babbitt metal and the dark color brass composition. Fig. 3, and the sectional view on the right of Fig. 2, shows the application of the packing to an engine.

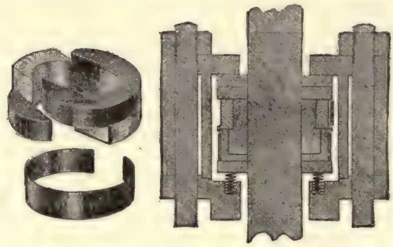


Fig. 2.—Tripp's packing.

Mitchell's Metallic Packing is shown in Fig. 4. It consists of metal and elastic rings alternated. The metal rings are of triangular section, and compression of the round elastic rings on their beveled sides forces them inward against the rod. The cut showing a packed rod shows three elastic rings with four metal rings. The metal rings are made in half-sections, divided by a brass space ring. They are put in so as to break joints at right angles.

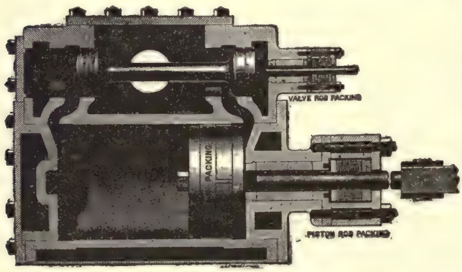


Fig. 3.—Tripp's packing.

Fig. 4.—Mitchell's packing.

The "Common Sense" Metallic Packing is shown in Fig. 5. It consists of rings of granulated metal inclosed in a cotton tube, alternating with soft metal rings. When applied, the granulated coils are firmly packed in place, and hammered down solid and even all around the rod, thus adjusting themselves to both rod and box.

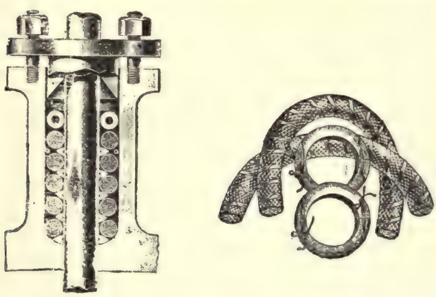


Fig. 5.—"Common Sense" packing.

Deeds' Metallic Packing is shown in Fig. 6. It is made of babbitt and other anti-friction metals. The packing consists of four segments placed in position in the form of a cylindrical shell about the rod, and beveled off at each end. Two of the segments are wedge-shaped, with the base resting against the rod. There are one or more recesses or grooves on the inside of each segment, which, when joined together, form a complete chamber around the rod. This chamber is for lubricating purposes, and, when filled with oil and condensed steam, reduces the bearing of the metal to a minimum. This peculiar construction enables the packing to readily adjust itself to the variations of the rod and remain tight, and also to follow its wearing surfaces, and when there is any, to take up its own wear. The metal is kept in position by elastic rings. In the bottom of the stuffing-box two or more of these rings are placed, one of which is larger than the other, to fit the bevel of the packing. In

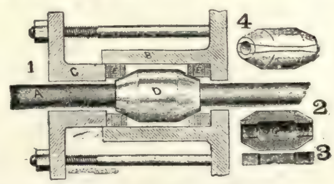


Fig. 6.—Deeds' packing.

making the adjustment, these rings are first put in position ; then the packing, with its interior cavity filled with lubricant, is placed around the rod and pushed down into the stuffing-box. Then two more rings are fitted to the opposite end of the metal, and pressed into the box. The gland is then screwed down into position. These rings do not touch the rod or stem, but only serve to retain the segments of metal in position when once fitted, and to yield in case of any slight deviation of the rod from a straight line. Referring to Fig. 6, *1* is the packing and stuffing-box complete : *2*, sectional view, showing condensing chamber *G ; 3*, Wedge-shape segment of same ; *4*, End-view of packing on piston *A*. *A A*, Piston rod. *B*, Stuffing-box. *C*, Gland. *D D*, Metallic packing complete. *E E E E*, Elastic rings. *G*, Condensing or lubricating chamber.

Garlock's Packing is shown in three forms in Figs. 7, 8, and 9, known as the elastic ring, the sectional ring, and the spiral packing, respectively. It is a combination of rubber and cotton, woven together as shown, and filled with finely divided graphite.

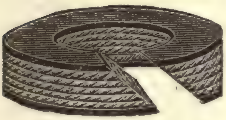


Fig. 7.

Fig. 8.—Garlock's packing.

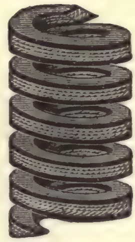


Fig. 9.—Garlock's packing.

Steam Piston Packing.—Prof. John E. Sweet (*Trans. Am. Soc. Mech. Engrs.*, Vol. IX.) proposes a new principle in steam-piston packing, which is shown in Figs. 10 and 11. It is a common eccentric ring hooked together by a clamp which forms a part of the ring itself, and this hook clamp limits the expansion of the ring and changes the whole principle of its action. The rings are cast heavy, rough-turned very much larger than the cylinder, a piece cut out, sprung together, and fitted with the hook clamp or shoes, left slightly larger than the cylinder, and then returned to a tight fit. It will be noticed that the rings can compress to a limited extent, but cannot expand. In use they act, or are supposed to act, as follows :

When the engine is first started and the hot piston moves to the cold end of the cylinder, the rings compress and allow it to go free ; but when both cylinder and piston get up to working temperature, the rings just fit and work without any pressure and very little tendency to wear. Filing out the hooks compensates for wear when it has taken place. It will be seen that the hook clamp is longer at one end than the other. The object of this is to break joints when two rings are placed side and side in the same groove, and thus cut off the leak which would otherwise take place through the gaps.

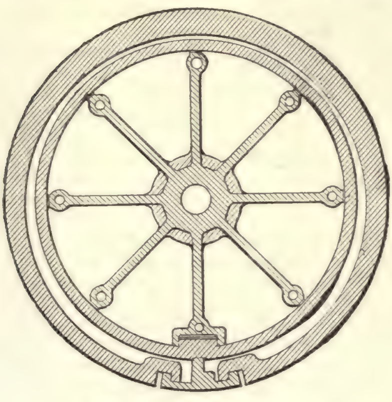


Fig. 10.—Sweet's packing.

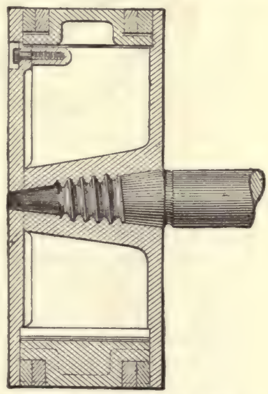


Fig. 11.—Sweet's packing.

The hook clamps or shoes are placed at the bottom of the piston, in the horizontal engines, and secured by leaving them a tight fit and allowing the follower to bind them fast. Figs. 10 and 11 show the arrangement as used in a large piston with spider, bull ring, and follower, and the method of lining up the rod with liners between bull ring and spider. The objection to the plan is that it is only applicable, with any prospect of success, to parallel cylinders, a thing not always obtainable.

Duval's Metallic Packing consists of fine filaments or wires of hard brass laid up into strands and then braided to form gaskets of various cross sections.

Panel Raising : see Moulding Machines, Wood.

Paper Cutters : see Book-binding Machines.

Pea Harvester : see Harvesting Machine, Grain.

Pebbling Machines : see Leather-working Machines.

Petroleum Engines : see Engines, Gas. **Fuel :** see Locomotives.

PHONOGRAPH. This instrument has undergone many improvements, but it cannot be said yet to have come into commercial use. As now constructed (Fig. 1) it is mounted on a hollow wooden base, which contains an electric motor. The spindle of the motor extends from the top of the base and drives a governor which can be adjusted to produce any number of vibrations a minute, within limits. It also drives the phonograph itself. The spindle on which the main driving-pulley is fixed is carried in two bearings, and the part between the bearings is very finely screw-threaded, and an extension of the spindle carries a taper

brass mandrel, on which the cylinder which receives the record is slipped. The fine-threaded screw serves to give the feed to the diaphragms, carrying them lengthwise of the wax cylinder, so that the style traces a helix which is of the same pitch as the screw.

There are two diaphragms—the first of glass, for receiving and recording the message, and the second of silk for interpreting the record, and articulating it afresh. Both diaphragms are enclosed in metal cases having openings to which flexible tubes are connected. The listening tube is bifurcated, and at each extremity carries a small, bent nozzle which rests easily in the ear. The other tube, which is shown lying beside the instrument, is an ordinary speaking tube. In the centre of each diaphragm is a style, the one for engraving being stiff and sharp, while the other is hook-shaped, so that it drags over the record without any tendency to cut down the elevated portions. The frame which carries the diaphragm can tilt on the back guide, its weight being carried by a set-screw sliding along the rail in front of the cylinder. By means of this screw, the style can be adjusted exactly in relation to the wax cylinder. The rail is carried by a cam by which it can be raised at will, the cam being turned by hand, or in some cases by the foot of the operator. A partial movement of the cam lifts the style clear of the wax cylinder, and at the same time tilts the back frame, lifting the part nut off the screw. Thus the instrument is thrown out of action. By turning the cam still further, a finger on the nut lever is brought into engagement with the comparatively coarse-threaded screw shown in front, and then the frame with the diaphragm is moved rapidly back. The wax is of considerable thickness, so that after it has once served its purpose, its surface is skimmed off. To enable this to be done, there is attached to the under side of the plate which carries the diaphragm, a cutting tool which always precedes the engraving style, and trims up the wax surface in front of it. One cylinder will serve for more than forty successive records.

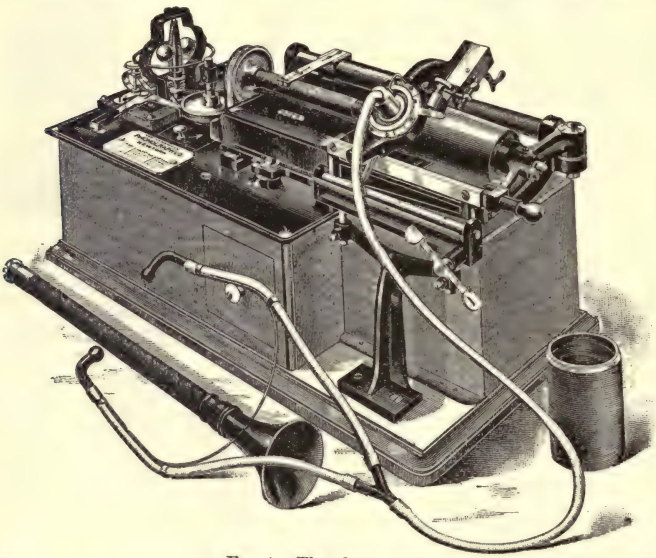


FIG. 1.—The phonograph.

The Graphophone.—Fig. 2 shows the general arrangement of the Bell-Tainter graphophone. The instrument is mounted on a table provided with a lid which can be closed and locked when not in use. Underneath this table is fixed a balanced treadle and driving wheel, similar to those of a sewing machine. The cord from the driving wheel passes through the table and around a small pulley, to actuate the governing device, which is arranged to give speed of 160 revolutions per minute. In practice this speed can be maintained within one or two revolutions, no matter how fast or how irregularly the treadle is worked. From a pulley, on the other end of the governor, a cord passes to the main pulley of the instrument, which is fixed to the front of the table. This pulley is loose on a spindle which carries the centring drum that supports one end of the record cylinder. A similar drum, opposite the former, and at a distance from it corresponding to the length of the cylinder, runs free in a suitable bearing. This drum and its cylinder are capable of a lateral motion, controlled by a spring. To mount a cylinder upon its centres, the drum and its spindle are drawn back, the cylinder is

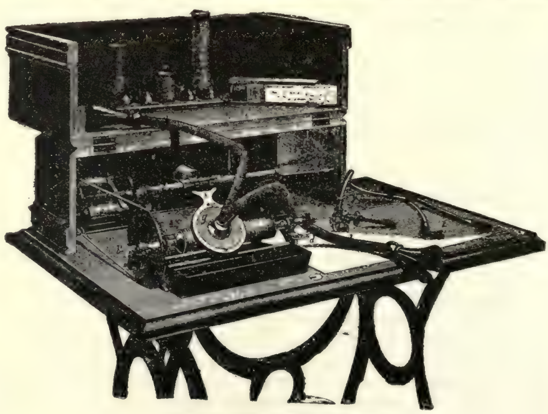


FIG. 2.—The graphophone.

put in position, and the spring is released, so that the cylinder is held tightly by its bearings, and any motion communicated to the driving pulley through the governor is of course imparted to it. In order to provide a means for starting or arresting the movement of the cylinder immediately—an operation absolutely necessary in operating the graphophone—the driving pulley of the instrument, which, as has already been mentioned, runs loose on its spindle, can be made fast with the latter at will by means of a clutch, which can be thrown in and out of gear by means of a system of levers operated by two buttons placed in the position shown in the engraving; by depressing one or other of these buttons or keys, the record cylinder can be stopped and started instantly.

The recording style is carried upon a tube which is fixed parallel to the cylinder, but at a higher level. The lower part of this tube is cut away, to expose a very fine-threaded screw placed within it. This screw is caused to revolve by means of toothed gearing driven from the main pulley, so that when this latter is running idle, the screw, as well as the record cylinder, is stopped. The circular box containing the recording diaphragm is carried at the end of a short arm which terminates in a half-sleeve, of the same diameter as the tube enclosing the screw. Hinged to this half-sleeve is another similar one, from which projects a short arm carrying at its end a relatively heavy balance weight. Set in a slot made in the half-sleeve first referred to, is a portion of a nut, threaded to the same pitch as the screw; at the back of this nut is a spring which keeps it projecting slightly beyond the face of the sleeve, but which allows it to pass back into the recess if a slight pressure be applied. The position of the parts is so arranged that the style attached to the centre of the diaphragm slightly penetrates the wax film with which the record cylinder is coated, and in this way a very fine screw of 160 threads to the inch, and one-thousandth of an inch in depth, is traced upon the cylinder. We now come to consider the construction of the recording part of the instrument, the function of which is to receive the sound vibrations and to engrave them faithfully upon the wax surface. It consists of the shallow circular box, referred to previously as being attached to the carrying sleeve. The diaphragm forming a bottom to this box, is made from a piece of very thin and flawless mica; a short distance above, and parallel to it, is fixed in the box a metal plate, pierced with two series of concentric slots; above this again, but not in contact with it, is a metal cone, the centre of which coincides with the center of the box, and is therefore immediately over the style attached to the mica. All these parts are enclosed within the box by a metal cover with a central opening, to which is attached a flexible speaking-tube, provided with a mouthpiece. In front of the mica diaphragm, and stretching from one side of the box to the other, is a metal bridge, so placed that it is almost in contact with the style. In the centre of this bridge a projection is formed, of such a shape that when the instrument is in operation it presses upon the wax surface of the recording cylinder and burnishes it in advance of the style, so that the latter may have an absolutely true surface to work upon.

The style is simply a very fine, chisel-pointed cutting tool, capable of forming a perfect thread upon the wax-coated cylinder, of the pitch and depth already mentioned. In engraving, the carrier is placed upon its tube so that the style bears upon the cylinder; the driving pulley is set in motion; the message is delivered through the mouthpiece of the speaking-tube, and the air vibrations thus created strike upon the cone within the receiving box, and are distributed uniformly over the surface of the mica diaphragm with the aid of the slotted plate, setting up in the latter a series of vibrations corresponding to the sounds produced by the speaker and transmitted through the tube.

The transmitting or repeating mechanism consists of a light carriage for carrying the socket, to which the transmission tube is attached, as well as the diaphragm and its attachments. On this carriage are four curved arms; the back pair fixed, and the forward pair hinged to the carriage and controlled by springs. A threaded block or nut, similar to that already described as forming part of the receiving mechanism, is fixed between the forward pair of arms; at the back of the carriage, and rigid with it, is another pair of arms with connecting pieces at top and bottom; this serves as a handle for holding the transmitter when it is taken off or put on the instrument. The front part of the carriage terminates in a screwed tubular socket which forms a continuation of the nozzle on which the elastic transmitting tube is fixed; upon this socket is screwed the circular box, containing the transmitting diaphragm. The under side of the box is pierced with holes to prevent the setting up of air currents within, which might interfere with the proper action of the diaphragm. A hollow stem, terminating in a curved beak, forms a part of the bottom of the box. To the centre of the diaphragm, which is of mica, is attached one end of a silk thread, the other end being fastened to a small curved style, which is secured to the beak by a pin in such a way as to give it entire freedom of motion. If now a record has been engraved by the recording style upon the wax-coated cylinder, and the recording diaphragm with its attachments has been removed, the transmitting carriage is slipped over the tube containing the traversing screw. In doing this the nut between the pair of arms engages with the screw, the point of the curved style enters the groove engraved upon the cylinder, and on the instrument being set in motion the irregularities which had previously been engraved by the recording style give a corresponding motion to the transmitting point, and, by means of the silk thread, which is kept in tension, set up in the transmitting diaphragm a series of vibrations similar in character to those which had been previously created in the recording diaphragm by the message spoken into it. In this way the original sounds are faithfully reproduced as to quality, but not as to intensity, perhaps owing to the smaller diameter of the repeating diaphragm, but they are not audible excepting through the intervention of the transmitting tube. This tube, which is slipped over the nozzle, is bifurcated near its outer end.

The governor, which maintains a constant speed of the record cylinder and the feed screw, consists of a light frame secured to the table, carrying a spindle on which the device is mounted. Loose on the spindle near the right-hand end of the frame are a disk and pulley, made in one piece ; a belt from the treadle passing over drives the governor. The driving pulley which gives motion through a belt to the instrument, is fast on the spindle, and is formed with a boss on the inner side. A third disk is held in contact with the leather facing on this latter by a strong spiral spring abutting against the boss of the pulley, and a disk close to the cross arm keyed to the spindle. Pinned to the ends of this arm are the two weights, and two short arms project from them at the point where they are pinned to the cross arms, the end engaging in a groove formed in the boss of the disk. Two small pins pass from these arms through the boss on the arm, and into the disk against which the spiral spring presses. It will be seen that this spring holds the disk in close contact with the other disk—sufficiently so that when motion is transmitted from the treadle to the pulley, the governor is caused to revolve, and a belt from the pulley to the instrument gives the desired motion to the cylinder and driving screw. So long as the speed continues normal, the instrument is driven at the rate for which the different parts are arranged, but should an extra velocity be given, the weights of the governor open slightly, and the pressure between the disks is reduced so that the speed falls instantly. So nicely are the various parts adjusted that with the most ordinary care, the normal rate of 160 revolutions per minute, to which the instrument is speeded, need never be exceeded by more than one or two revolutions.

The Gramophone.—Among the instruments for recording and reproducing speech and other sounds, the invention of Mr. Emile Berliner, of Washington, D. C., known as the gramophone, is remarkable as being distinct from the others in both form and principle. The gramophone was one of the early modern talking machines. It was nearly perfected when the latest form of phonograph appeared. Since that time it has been improved, and we understand that recent trials of the instrument in Europe have proved very successful.

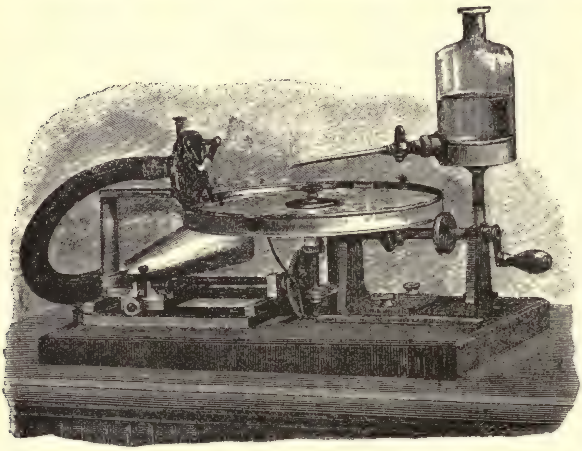


FIG. 3.—The gramophone.

Fig. 3 shows the recording apparatus ; Fig. 4, the reproducer ; Fig. 5, a print of a gramophone record.

In this machine a central apertured disk of zinc is used for receiving the record. The disk, which is covered with an extremely thin film of wax, is mounted on a vertical spindle within an etching trough which revolves with the spindle. The recording style, the diaphragm, and the mouth of the tube are mounted on a carriage, which is moved toward the centre of the zinc disk by a screw, taking its motion from the spindle carrying the disk. Motion is imparted to the record disk by a friction wheel on the horizontal shaft at the right of Fig. 3. This shaft is provided in the present case with a hand crank, by which the plate is revolved. The same shaft is also provided with a pulley for receiving a belt from a suitable motor, when it is desired to operate the machine by power.

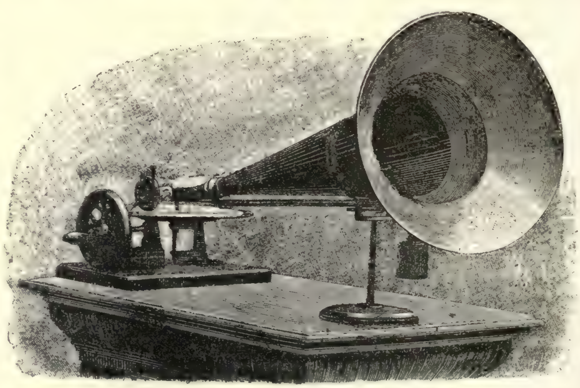


FIG. 4.—The reproducing apparatus of the gramophone.

As the record disk is revolved, sounds uttered in the mouth-tube cause the diaphragm to vibrate, and the style is moved in a direction parallel with the face of the record surface, forming in the wax film a sinuous line representing the sounds uttered in the mouth-tube. As the

plate revolves, the style and parts connected with it are carried forward toward the centre of the disk, thus forming a spiral, sinuous line in the wax film. When the record is complete. the style is removed, and acid is admitted to the etching trough from the bottle supported at the right of the machine. As soon as the plate is sufficiently etched, the trough is removed, the acid is returned to the bottle, the wax film dissolved off, and the plate is transferred to the reproducing apparatus shown in Fig. 4.

In this apparatus the record plate is mounted on a vertical spindle, and revolved as in the other case. The diaphragm of the reproducing instrument carries a style which follows the spiral groove in the plate, thus causing vibrations in the diaphragm, similar to those produced by the sounds uttered in the mouth-tube of the recording instrument. The diaphragm cell and reproducing style are carried upon the smaller end of the trumpet, which is delicately pivoted on a standard, and counterbalanced so that the reproducing stylus exerts only a slight pressure upon the record plate. The volume of sound issuing from the trumpet is great. Instrumental and vocal music are faithfully reproduced. It is obvious that the records formed by this instrument are permanent, and the plates capable of being stored in a very small space. The possibilities of extending the gramophonic principles are perhaps more noteworthy than its present development. The disks can be easily duplicated, and at an exhibition in Philadelphia an electrotype copy of a 12-in. disk was shown which sounded precisely like the original. Since then talking copies have been made by pressing a matrice into molten glass, but the liability of the glass to stick in the form—the matrice being of copper—and the consequent warping of the glass copy, has proved a serious objection. Steel matrices have been suggested as liable to overcome this difficulty. Very successful copies have been made in celluloid from electrotype matrices, and such celluloid copies are particularly free from all frictional noise, provided the celluloid is pressed hard, and of well-seasoned material. Gramophone records have been printed, and such prints have been photo-engraved, and the copy thus obtained sounded precisely like the original. The important subject of good articulation has ever been kept in the foreground, and this is now in so satisfactory a shape that the inventor has carried on a vocal correspondence with friends in Europe, by means of small gramophone disks, which can be mailed in a good-sized letter envelope.

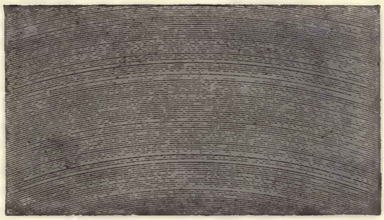


FIG. 5.—Gramophone record (reduced).

Picker : see Cotton-spinning Machines. Also Harvester, Cotton.

Picking Table : see Ore-dressing Machinery.

PILE DRIVING.—Drop hammers are now made to weigh from 75 to 4,200 lbs. They are much longer for a given weight than the older forms, thus avoiding the sidewise throw when the hammer strikes near one edge. Wear is thus diminished and the effect of the blow increased. The bottoms of the hammers are made concave, while the sides are cored, as shown in Fig. 1. Dies are of hammered steel, triangular in form, fitted in the hammer and stationary, or are arranged to rotate on a turned pin which is keyed in the hammer. These forms of die are used with nippers. Where driving is done by friction, the hoisting line is attached directly to a turned steel pin.

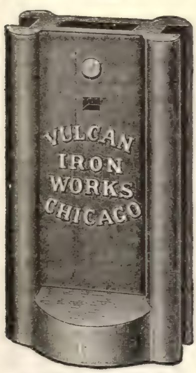


FIG. 1.—Pile hammer.

In the operation of pile driving it frequently happens that the piles are either split or "broomed" on their tops by the concussion of the hammer. To overcome this difficulty, recourse has been had to metal bands around the upper ends of the piles. This is expensive and wastes time. Casgrain's cap, illustrated in Fig. 2, is intended to overcome the trouble. It consists of a cast-iron cap with tapered recesses above and below, the chamfered head of the pile fitting the lower one, and the wooden block, *D*, fitting the upper one. Suitable jaws, similar to those on the hammer, engage the leaders and form a movable toggle-iron, steadying the pile as it is being driven. As the hammer descends, it strikes the timber or cushion block set in the upper cavity, and the pile is forced down by the blows. When the pile is driven, the short chains on either side of the hammer are connected to the caps by means of pins, and both hammer and cap are hoisted up and secured for another operation.

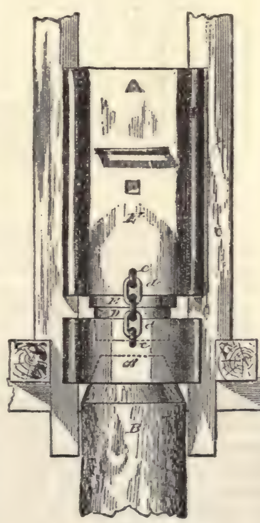


FIG. 2.—Pile cap.

In order to prevent the grinding action of the drop hammer on the leaders, it is usual to protect them with iron wearing pieces known as "liner irons." The most modern form of these consists of a channel-iron liner protecting the entire face and corners of the leaders. They are made in full lengths to avoid joints and to add to the strength of the leaders.

Pile Drivers.—Fig. 3 represents a pile driver intended for township work. It is provided with leaders 25 ft. high, and with a hammer weighing from 800 to 1,200 lbs. The hammer is handled by horse power, one end of the line being fastened to a suitable post, while the other end is passed through a pulley block, which is fastened to the main hoisting line and leads to the whiffletree direct. Fig. 4 represents a pile saw arbor made to cut off piles 16 to 24 ft. under water. The shaft is 3½ in. in diameter, and counterbalanced. A 42-in. saw, at a speed of about 600 revolutions, is usually employed. The arbor works on a spline over its entire length, and is easily adjustable to any depth within its range. The belt runs on side rollers and frames fastened to the inner side of the leaders.

FIG. 3.—Pile driver.

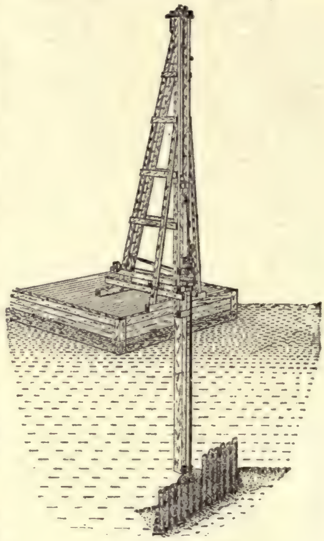


FIG. 4.—Pile saw.

The hoisting gear for steam pile drivers is usually an engine of simple construction, provided with means for sustaining and lowering the load. Friction-drum engines, the drums being cones of wood and iron brought into contact while hoisting by means of thrust screws, are employed. The following table shows the dimensions of engines, boilers, etc., of the Vulcan Iron Works pile drivers:

Single Cylinders.

Hoister No.	Dimensions of Cylinders. Diam., in.	Dimensions of Cylinders. Stroke, in.	Weight hoisted, single rope, lbs.	Hoisting Drum. Diam., in.	Hoisting Drum. Length, in.	Dimensions of Boiler. Diam. shell, in.	Dimensions of Boiler. Height or length of shell, in.	No. of Tubes.
1	6	8	1,350	12	24	28	68	38
1	6	12	1,750	12	24	30	72	40
2	6	12	1,750	14	24	30	110	30
1	7	12	2,750	14	24	34	78	52
2	7	12	2,750	14	24	32	110	34
1	8	12	3,000	14	26	36	80	56
2	8	12	3,000	14	26	36	117	46

Double Cylinders.

1	6	8	2,000	12	24	36	74	56
2	6	8	2,000	12	24	36	117	46
1	6	12	3,000	14	26	36	80	56
2	6	12	3,000	14	26	38	120	50
1	7	12	4,000	14	26	42	86	80
2	7	12	4,000	14	26	42	136	62

Steam Pile Hammers.—These hammers are raised by the engine in the leaders and allowed to rest full weight on the pile. Steam is then admitted to the hammer cylinder, causing the piston carrying the hammer head to reciprocate so that the hammer pounds automatically until the pile is driven as far as may be required. The Vulcan-Nasmyth hammer, represented in Fig. 5, has the novel feature of a positive valve gear capable of adjustment for long or short strokes, operated by the movement of the hammer, and delivering either an elastic or non-elastic blow at will. A rigid connection between the steam

FIG. 5.—Steam pile hammer.

cylinder and lower bonnet is obtained by four turned steel columns fitting into reamed holes in the cylinder and bonnet, and secured by heavy keys.

The hammer proper has four holes bored out, through which the rods pass. As these rods are turned the entire length, and the holes in the hammer bored out with just sufficient play, it is evident that the hammer cannot cast and break the piston-rod. Breakage of the bonnet is avoided by placing the rods in the corners of the bonnet, leaving the full section of the metal between unimpaired by bolt or rivet holes. The action is regular and continuous. The manufacturers claim that any kind of pile can be used. hard or soft, straight or crooked, and driven to any depth without injury to the head of the pile, in the hardest kind of driving, sand or hard pan ; and that the most ordinary kind of timber, such as spruce, bass, and pine, can be thus driven withont the use of head bands.

The following table shows the dimensions of these hammers:

Table of Vulcan-Nasmyth Steam Pile Hammers.

No.	Weight, lbs	Length, ft.	Diameter. Cylinder, in.	Nominal stroke, in.	Weight of striking parts.	Distance between jaws.	Width of jaws.
1.....	7,300	11	12	36	4,200	20	8½
2.....	5,000	9	10	30	2,800	19	7¼

Car Pile Drivers are widely used in the construction of railroads. These are of especial construction, and must possess great capacity, durability, and facility of operation in order to keep pace with the phenomenal rapidity of the track layer. A novel form of apparatus, swivelling on the centre to work at either end, is represented in Fig. 6. The type of hammer employed is the steam hammer last above described. The dimensions are as follows : Length of car, 34 ft.; centre of forward axle to centre of pile, 8½ ft.; centre of forward axle to centre of pile, with forward truck moved back, 16 ft.; lateral swing either side of centre, 9 ft.; extreme height above top of rail, with leaders lowered, 15¼ ft.; total length of leaders to under side of head block, 36 ft.; weight of drop hammer, 2,000 lbs The leaders are raised and lowered by the engine. The swinging pinions are operated by ratchet wrenches. The car itself is symmetrical about the pivot point, so that the carriage may be swung around end for end. Driving can be done at either end, with equal ease. The machine may be made self-propelling, and this mechanism is likewise quite independent of the position of the carriage upon the car, whether at one end or the other, central, or swung out at work. The engine is of a special form, and the boiler is upright to save length. We are indebted to the Vulcan Iron Works of Chicago for the foregoing information.

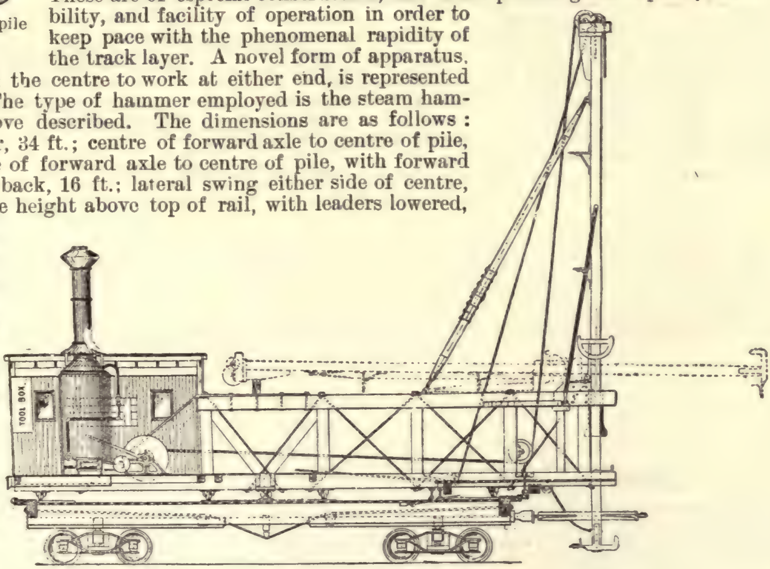


FIG. 6.—Car pile driver.

PIPE AND TUBE MAKING MACHINES. I. NEW PROCESSES OF MAKING SEAMLESS TUBES.—The manufacture of tubes without soldering has in recent years been the object of persistent research and important labors that have originated several new processes, among which those of Messrs. Flotow & Leidig, Robertson, and Mannesmann are especially worthy of notice.

The first of these processes, which is of limited application, employs a method of longitudinal drawing upon a stationary mandrel. The two others have recourse to a helicoidal or diagonal drawing, accompanied with a cooling of the metal, on a fixed or movable mandrel, by the aid of revolving draw plates or rollers having a differential rotation. They constitute two of the most remarkable examples of the flow of solids through metals.

Up to the present, the Robertson process appears to have been applied with the most advantage to the working of plastic metals (copper, tin, bronze, etc.) in a cold state, while that of Mannesmann, which is of the most remarkable boldness and originality, is perfectly adapted to the manufacture of iron and steel tubes. This mode of manufacture, which is now worked in Germany on a large scale, produces, at a low price, absolutely homogeneous

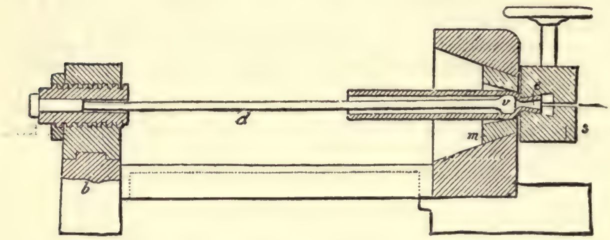


FIG. 1.—Flotow & Leidig process of tube making.

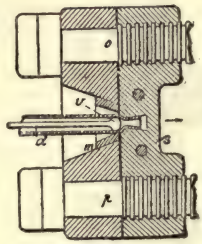


FIG. 2.

seamless tubes, whose metal, far from being weakened, is strengthened by the operations that it undergoes.

The Flotow & Leidig Process.—In the process of drawing employed by Messrs. Wilhelm von Flotow and Hermann Leidig, of the Dantzig Arms Manufactory, the mandrel, *d* (Figs. 1 and 2), is fixed, and the ingot is drawn between the head, *v*, of the mandrel and the draw plate, *m*, in such a way as to convert it into a tube of smaller diameter. To this effect,

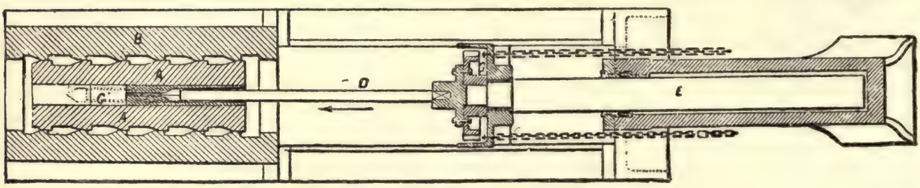


FIG. 3.—Robertson process of tube making.

the ingot is held by its tenon and mortise extremity, *e*, in the head, *s*, which is movable under the action of the screws, *o* and *p*. Through successively reducing the diameter of the draw plate, this process permits of drawing out a tube conical externally, like a gun barrel.

The Robertson Process.—The mandrel, *D* (Figs. 3, 4, 5), of the apparatus of Mr. James

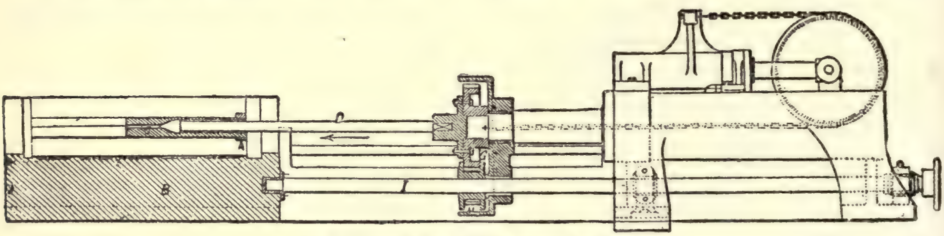


FIG. 4.—Robertson process of tube making.

Robertson, of Glasgow, revolves within the ingot, *C*, and is at the same time pushed forward by the hydraulic press, *E*. The rotary motion is given by a train, the pinion of which is fixed by tongue and groove to the shaft, *I*. The draw-plate, *A*, which is firmly keyed between the jaws, *B*, is slightly conical, so that the ingot, *C*, fixes itself in the die by the very pressure of the mandrel. The form of the mandrels varies according to the metal and temperature of the ingot. The one shown in Fig. 5 serves to convert cold copper and soft steel ingots into thick sided tubes that are afterward drawn out. The point is provided with three longitudinal grooves, enlarged from the point to the base, and with rounded sides, so as to displace and face back the metal without cutting it, and designed likewise for the passage of the petroleum for lubricating the point when ingots of copper are thus treated in a cold state. The velocity of the tool at the circumference is then but about 3 in. per second, although it is very rapid (40 ft. per

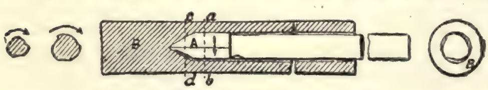


FIG. 5.—Robertson tube mandrel.

second) when hot steel ingots are being pierced, without a possibility of oiling the point. The advance of the tool in this case is about 5 ft. per second.

The Mannesmann Process.—In Messrs. Reinhard & Max Mannesmann's process the seamless tubes are obtained by rolling solid bars. As shown in Fig. 6, at *1*, the bar, *B*, is held between two cones A *a*, revolving in the same direction, and the axes of which point in opposite directions in parallel planes. The converging sides of the cones, between which the bar is held, draw out the metal at its periphery in such a way as to gradually make it assume the form of a tube, the beginning of which is seen at *b*. When the finished tube comes from the roller, as shown at *2*, there remains a blank, *B*, hollowed out at b^2, through the pressure of the cones. The cones are nearly always hollow helices with pitches increasing from the point to the base, so as to draw out the surface of the bar progressively in measure as it advances between the cones. If it is desired to avoid the blank shown in *2*, it will suffice

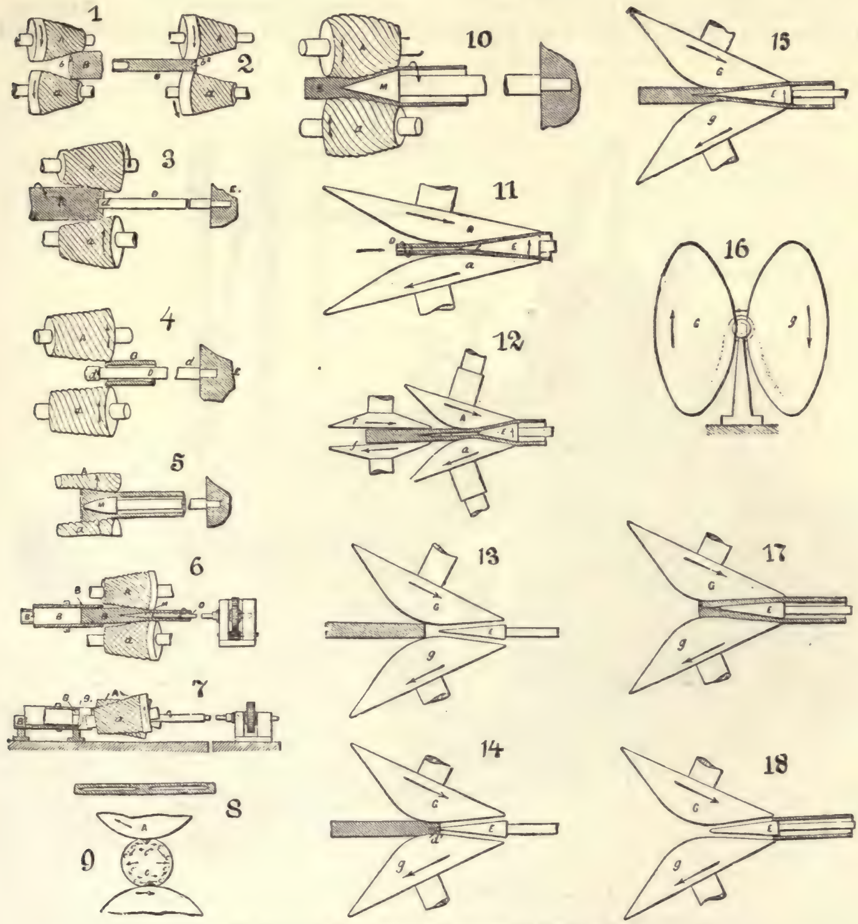


FIG. 6.—The Mannesmann process of tube making.

to push the tube submitted to drawing over a mandrel, *D* (*3*), which revolves in a bearing, *E* (*4*). For softer alloys, which may be rolled in a nearly cold state, a conical mandrel is employed (*M*. *5*), and this, if need be, can be kept cool by a stream of water, and serve to increase the diameter of a tube already formed. This mandrel terminates in a grooved point, and can, as shown at *6* and *7*, revolve in the same direction as the ingot, or the opposite, according as it is desired to retard or hasten the drawing around the point of the mandrel. The process by means of which the tubes shown at *8* are obtained, is founded on the principle that an ingot rolled diagonally between two cones (*A* and *a*, *9*), revolving in opposite directions, undergoes at the bearing point distortions that are distributed over the triangular wheels, *c c*, which cause within the ingot molecular stresses, whose resultant tends to distend its fibres all around its axis, in measure as it revolves between the cones. The tubes thus formed are smooth within. Their fibres are not broken, but lengthened out spirally around their axis. The apparatus represented at *10* serves for manufacturing copper tubes of uniform thickness, and of a diameter greater than that of the ingot. The point of the mandrel pene-

trates the ingot very easily without heating it much. In a new variant of their process, Messrs. Mannesmann substitute mushroom-shaped rollers, *a a* (*11*), for the cones. The intersection of the vertical planes passing through the axis of rotation and through the apices of the rollers is situated in the vertical plane passing through the axis of the ingot, *D*, and mandrel, *E*. Moreover, the angle, *e*, of the mandrel is a little more open than that of the rolling generatrices of the mushroom-shaped rollers, so that the lamination compresses and reduces the thickness of the sides of the tubes on the mandrel, while its diameter at the same time increases. From *12* will be seen how a tube may be made by means of two successive operations, one of them preparatory, and consisting in tubing the axis of the ingot by the diagonal rolling of the plates, *F f*, and the other a finishing operation, consisting in widening the tube on the mandrel, *E*. In this case the rollers, *A a*, may be given a velocity such as to make the mandrelled part of the tube rotate more rapidly than that part of the ingot submitted to the action of the plates, *F f*.

Diagrams *13* to *18* show how it is possible to make a tube directly with but a single pair of rollers, *G g*. Before approaching the mandrel, *E*, as shown at *14*, the ingot (*13*), held

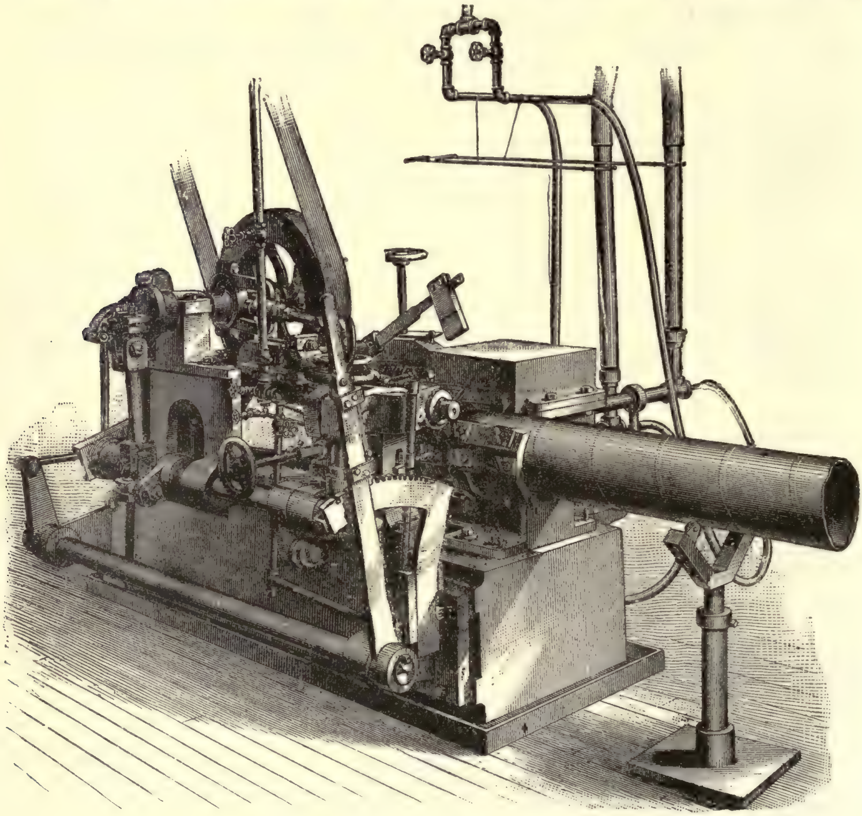


Fig. 7.—Manufacture of spirally welded tubing.

between the converging generatrices at *G g*, undergoes a preparation that reduces its diameter and hollows its extremity at *d′* (*14*), so that it can favorably meet the point of the mandrel in passing from the converging to the diverging generatrices of the rollers. The tubular part of the ingot is then, as shown at *15*, pushed along and compressed on the mandrel through the gradual action of *G g*, and converted into a thin-sided tube, until the posterior end of the ingot leaves the rollers. When the entire manufacture of the tube is effected by means of a single pair of cones, it is necessary that the torsion given to the ingot by the converging generatrices during the first part of the operation (*13* and *14*) shall not be destroyed during the widening and calibrating (*15*, *16*, *17*), because such torsion, which winds the fibres spirally around its axis, considerably reduces its resistance to internal pressure. To this effect, the rollers are given a profile and inclination such that the vertical planes passing through their summits, situated (as shown at *18*) at different levels, intersect each other in the vertical plane of the axis of the tube. The tube thus rolls without torsion between the divergent generatrices. Other descriptions of Mannesmann's tube process may be found in Trans. A. S. M. E., vol. viii., p. 564, and Trans. Am. Inst. Mining Engrs., vol. xix., p. 384.

II. Spirally Welded Tubing.—The manufacture of spirally welded tubing, as carried on at the works of the Spiral Weld Tube Co., Orange, N. J., is thus described: The raw material of the industry is the sheet-iron or steel of commerce, of such lengths and widths as it is convenient to roll. The range of the gauges of the metal which can be employed has not yet been determined. The lightest metal thus far successfully made into pipe is No. 29 iron, and the heaviest a steel gauging ·165 of an inch in thickness, or No. 8 of the Birmingham gauge.

The first step in the process of manufacture is to slit the sheets into bands of the width most convenient for the production of the desired diameter of pipe. The wider the skelp, the faster the pipe is made. For convenience, all diameters are made from four widths of skelp, 6, 12, 18, and 24 ins. To make a 6-in. pipe 30 ft. long from 12-in. skelp, it is necessary to have a ribbon of metal about 49 ft. long. The ends of the strips of skelp are united by a machine known as a cross welder. The sheets are so placed as to give about $\frac{1}{2}$-in. lap, and in this position they are firmly clamped. Heat is then applied by furnaces above and below, which move along the seam. As they recede, the hot edges are welded between a hammer moving vertically and an anvil of reciprocal motion. To place and clamp the skelp, heat the overlapping edges and weld them, consumes about one minute to each cross seam of 12 ins. A pressure of the foot of the operator upon a treadle engages a worm-wheel and worm, which rotates a reel upon which the skelp is wound. As it is drawn from the reel, it passes between pressure-rolls, which smooth out any buckling or other irregularity in the still hot metal, and rotary shears trim off the burr at the ends of the welded seam. In case the weld is defective or the sheets have not been clamped in line, the weld is cut by a shear held suspended when not in use, and the ends are welded again. As a rule, the weld is smooth and perfect, and the extra thickness of metal at the weld occasions no inconvenience in forming the pipe.

The pipe-machine (Fig. 7) is chiefly made of heavy castings, requiring but little finish.

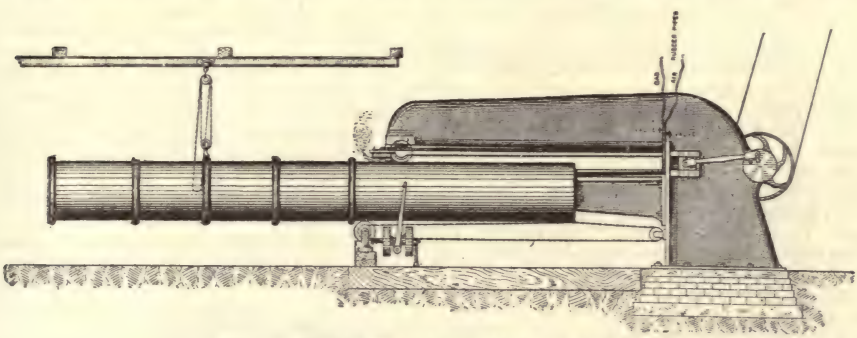


Fig. 8.—Machine for making welded steel pipes.

It occupies about 3 x 6 ft. of floor space. The reel carrying the ribbon of skelp is put in position, and one end of the metal is placed upon the guide table, which is set at the angle due to the width of the skelp and the diameter of the pipe into which it is to be made. The metal is carried into the machine between feed rolls geared together, which are actuated by a ratchet, giving them an intermittent rotation, and a rate of feed variable between $\frac{1}{20}$ and $\frac{5}{8}$ of an inch at each impulse, at the pleasure of the operator. This carries it into the forming jaws, which bend it to the desired curvature—the forming being effected by pinching the metal in curved jaws. The essential features of the pipe-machine are a guide table for the skelp, adjustable to the desired angle; feed rolls, to pass it forward with an intermittent progress, so that it shall advance when the hammer is raised and be at rest when the hammer falls: a former, to curve the metal to the desired radius, also adjustable: a furnace, to heat the metal: a hammer, to weld it, and an anvil to support the pipe, and receive the shocks of the hammer. No mandrel is used. The pipe in the forming process is held in place by a pipe-mould, which is a cylindrical shell, within which the pipe rotates as the stock is fed in. The anvil is of considerable mass, steel-faced, and extends the entire width of the skelp. The hammer is light, and at normal speed strikes 160 blows per minute. The heating is done in a furnace so constructed as to heat both the edges to be united for the space of several inches ahead of the point at which the welding is effected. A 6-in. pipe made of No. 14 gauge iron of good average quality, showing under test 33,000 lbs. elastic limit, and 50,000 lbs. ultimate strength, has a proof strength of 913 lbs. per sq. in., and an ultimate strength of 1,383 lbs. per sq. in. A 12-in. pipe of the same stock has a proof strength of 456 lbs., and an ultimate strength of 691 lbs. Using the same diameters and gauges of stock for comparison, the 6-in. spirally welded pipe weighs 5·2 lbs. per ft. against 18·77 lbs. per ft. for standard lap-welded pipe, and 28·28 lbs. for medium cast-iron pipe; the 12-in. spirally welded pipe weighs 10·46 lbs. against 54·65 lbs. for lap-welded, and 77·36 for medium cast-iron. The question of durability in service is one which naturally suggests itself when light steel or iron pipes are discussed. Experience on the Pacific Coast seems to have settled this question, as the cheap expedients adopted for water-conveyance during the

days when hydraulic mining was most extensively conducted have been followed ever since in permanent engineering works. Data on this subject are presented in a paper read by Hamilton Smith, Jr., before the British Iron and Steel Institute, and printed in Vol. I. of the *Journal* for 1886.

Cartwright's Pipe-welding Machine.—Figs. 8 and 9 represent a machine designed by Robert Cartwright, of Rochester, N. Y., for welding the longitudinal seams of steel pipes of large diameter. The general features of the machines are two compound air and gas furnaces, one internal and one external, immediately in advance of internal and external rolls, all being mounted on a frame to which a reciprocating motion is imparted by a crank, the seam of the sheet being welded being drawn between the furnaces and rolls as the weld is made. The gas and air are supplied through pipes attached to the reciprocating frame; and as their rear ends are joined to rubber hose, the movement of the frame is made possible. The sheet having been rolled to the required diameter, is held rigidly in shape by suitably designed removable clamps on the outside, and compression rings on the inside immediately under the clamps. These clamps and rings are quickly removed as the weld advances and without requiring the stoppage of the work. In starting to weld a seam the blowpipe jets of the furnaces heat the material, and as the pipe is drawn in the part longest in the flame comes to welding heat and is brought between the rolls and closed down to a perfect weld, the rolls being adjustable to suit different thicknesses of material. The machine consists of a base, *A*, formed with horizontally projecting arms, *B C*, so arranged as to create an elongated slot-way opening into the body of the machine. On the rear of the machine is mounted a crank pulley, connected by means of a pitman to a slide arranged as shown. To this slide are connected parallel bars, reciprocating in suitable guideways and carrying at their extreme outer ends the welding rolls and heating furnaces. The welding roll is guided on the frame of the machine. The sides of the frame in which the welding roll is journaled are reciprocated by means of the crank motion. Mounted in this frame is the main arbor, mounted upon which is the central welding roll, and two supporting rolls, all of which have friction bearings. These operate entirely independent of each other, and by their friction upon the main arbor they cause that to rotate more or less, the result being that when in operation each roll is constantly wearing against a different part of the main arbor, so that the latter is never worn out of true. The supporting rolls travel upon a track held adjustably to the frame by means of bolts. By adjusting in a vertical direction the rolls may be adapted to work upon thick or thin work, especially when welding the joint of a pipe, in which case one welding roll is used inside and one outside of the pipe, both being in the same vertical line. It is evident that this construction transfers all the strain of the welding pressure upon the roll to the arbor, and thence to the supporting rolls and trackway, and that the reciprocating movement of the roll does not abrade the metal at the weld, the operation being more nearly allied to that of annealing the hot metal at the joint, thereby preserving the fibre intact.

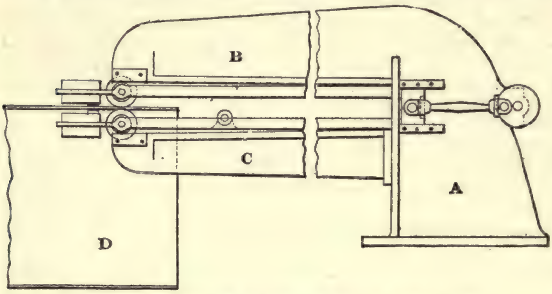


Fig. 9.—Machine for making welded steel pipes.

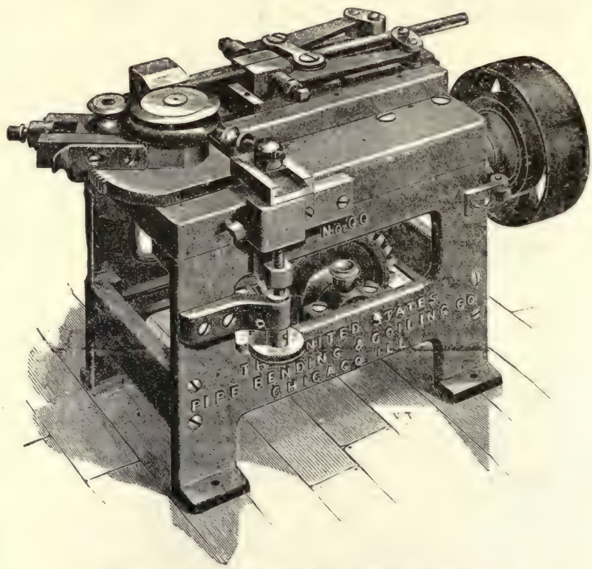


Fig. 10.—Pipe bending and coiling machine.

Pipe Bending and Coiling Machine.—Fig. 10 shows a pipe bending and coiling machine, made by the United States Pipe Bending & Coiling Co., of Chicago.

With this machine the heaviest of wrought-iron pipe or the lightest of brass or copper

pipe can be bent, coiled, or coned in any shape desired, without either heating or filling it, and, as claimed, with accuracy as regards the size of the bends wanted, or the diameter or spacing of the coils. Any number of a particular coil, as regards the diameter or spacing, can be made, the machine having been adjusted to the particular size wanted. This can be done at the rate of 3 ft. per minute.

The pipe is fed through the dies shown at the right in the cut, and through and around the circular dies at the left. The scale on the inside of the pipe, which is an accompaniment of hot bending, is entirely absent, and the inside is left as smooth as the outside, which in the case of brass and copper pipe needs no refinishing, as it is not marred. It is evident that any length of pipe can be bent or coiled. The machine illustrated will bend from 1 to 2-in. wrought-iron pipe, and the corresponding sizes in brass and copper.

PIPE COVERINGS. (See also BOILERS.) A form of pipe covering, Fig. 1, made by the United States Mineral Wool Co., consists of a metallic casing, made from steel plate, coated with lead, constructed with a lock which conceals the edge and enables the two edges to be permanently fastened with wood screws, forming a cylinder. One end of each cylinder is crimped and beaded to facilitate the making of an end joint. Perforated disks are used to support the cylinder, and secure the equal distribution of the "rock wool" with which the casing around the pipe is filled, and holding it up against the pipe. The rock wool is a silicate of lime and magnesia, made from a magnesian lime rock by melting the same in a cupola with blast, and turning the molten rock upon a jet of dry steam at 80 lbs. pressure. The melted rock is thereby blown into the form of a fibrous substance containing 97 per cent. of air, resembling wool in appearance. It is similar to mineral wool, or slag wool, which is made by blowing a jet of steam or air at high pressure into a stream of liquid slag as it flows from a blast furnace. Slag wool made from iron furnaces, however, generally contains sulphur, usually a lime sulphide, which tends to corrode iron pipes, and is therefore objectionable as a pipe covering. This objection does not hold in regard to rock wool.

FIG. 1.—Pipe Covering.

Magnesium carbonate has recently come into extensive use as a non-conductor of heat. The substance referred to is the artificially prepared basic carbonate of magnesia, a compound of the carbonate with the hydroxide. It is the "block magnesia" of commerce, the *magnesia alba* of the pharmacist. It is moulded to form coverings suitable for steam-pipes and their fittings, and sectional jackets for boilers and cylinders; it is furnished also in forms suitable for lining refrigerators, walls and roofs of buildings, fire-proof safes, etc. It is a smooth, white, close-grained solid, in outward appearance resembling a block of Paris plaster. It possesses the lightness of cork, the porosity of sponge, and withal a degree of firmness and strength that, in view of its levity, is quite remarkable. To examine more closely the properties of this substance, H. Luttgen (*Trans. Am. Inst. Mining Engrs.*, Vol. XV., p. 614) made the following experiment: A number of 1-in. cubes were sawed from the commercial block carbonate; also some bricks, that is, blocks measuring accurately 2 x 4 x 8 ins., the dimensions of an ordinary brick. The bricks were carefully measured and weighed, and placed in vessels containing distilled water, in which they became gradually submerged, owing to the displacement by water of the air enclosed in the structure of the magnesium carbonate. After twenty-four hours the blocks were removed from the water, dried superficially by contact with filter-paper, and weighed. From the increase in weight, the volume of the water absorbed, and consequently that of the air displaced by it, were obtained. The results showed that the air-cells occupied from 92 to 94·5 per cent. of the volume of the blocks. Mr. Luttgen made some experiments on the non-conducting power of various pipe coverings; a brief abstract of the results is given below. The experiments were made on 6-ft. lengths of 2-in. steam-pipe, which were covered with the different coverings, with results as follows:

Description of covering.	Diameter of covering, ins.	Weight per ft. in ozs., av.	Steam condensed, lb. per ft. per hr.	F heat-units per ft per hr.
1. Hair felt. Wrapped with twine. Burlap jacket	4½	12½	·076	69·02
2. Sectional carbonate magnesia. Asbestos paper jacket. Bands	4½	20¾	·083	75·29
3. Sectional carbonate magnesia. Canvas jacket. Bands	4½	20¼	·084	75·68
4. Sectional mineral wool. Asbestos paper, mineral wool, muslin	5¼	28¾	·085	76·68
5. Chalmer-Spence Co.'s covering. Asbestos, hair felt, paper	4½	28¼	·092	82·95
6. Shield's & Brown's covering. Asbestos paper, sheathing-paper	4½	27¼	·094	84·65
7. Reed's covering. Asbestos paper, felt paper	4¼	26¾	·099	89·62
8. Fossil meal pipe covering. Fossil meal, organic fibre	3¾	24	·127	114·54

With reference to the economy and cost of non-conducting materials, it may be said that the material which is in the greatest degree non-conducting, incombustible, and durable will prove the most economical, even though its first cost be greater than that of an inferior article. Experiments with naked pipes show that a 2-in. pipe carrying steam at 60 lbs. pressure

will condense 0.397 lb. per ft. per hour. Covered with a good covering like magnesium carbonate, the condensation, according to Mr. Luttgen, will be but 0·084 lb. per ft. per hour, a saving of 0·313 lb. per ft. per hour, or 3·13 lbs. of steam per day of ten hours, for each foot of pipe covered. The covering of 100 ft. of pipe, then, will save in a year of 300 ten-hour days the coal necessary to convert 93.900 lbs. of water into steam. One pound of bituminous coal is capable of making about 8·5 lbs. of steam, so the saving of coal due to the 100 ft. of covering would be 5½ tons per year, which, at $4 per ton, amounts to $22. The real saving will probably amount to more than this estimate in most cases; and it may be said in round terms that the 100 ft. of covering causes each year a saving of its own first cost ($25). Inasmuch as the material pays for itself in a year, and will last indefinitely under ordinary conditions, its advantageousness is beyond question.

An estimate of the waste of fuel in neglecting to cover steam-pipes has been made by M. Le Bour, who, referring to experiments made by M. Walther Meunier, gives the following as the quantities of steam condensed per hour and per year of 300 working days of 10 hours, per square foot of surface for different metals, with steam at about 260° F.

	Lbs. per hour.	Lbs. per year.
Copper	0·576	1,728
Wrought-iron	0·798	2,394
Cast-iron	1·712	2,136

Assuming that it requires an expenditure of fuel of 1 lb. of coal for every 7 lbs. of steam, the annual waste of fuel will be as given below for every square foot of the surface of the steam-pipe, and taking coal at $4 per ton, the loss per square foot of surface will be as in the second column.

	Lbs. coal wasted.	Waste of coal per annum.
Copper	245	$0·49
Wrought-iron	342	0·68
Cast-iron	305	0·61

A few years since, an investigation was made at the instance of the Boston Manufacturers' Mutual Fire Insurance Co., by Prof. John M. Ordway, of the Massachusetts Institute of Technology, upon the non-heat-conducting properties of various materials, some of which may be used for covering steam-pipes and boilers, while others, owing to their liability either to become carbonized or to take fire, cannot be directly applied to such use. The results of this investigation are given as follows in a circular (No. 27, December, 1889), issued by the insurance company to its members :

"In order that the relative merits of the different substances which are offered for preventing the escape of heat from boilers and steam-pipes, or as substitutes for wire lathing and plastering, or for tin plates in the protection of elevator shafts, or of woodwork nailed closely to walls, the following tables are submitted. These tables and extracts are taken from a report made by Professor Ordway. It will be observed that several of the incombustible materials are nearly as efficient as wool, cotton, and feathers, with which they may be compared in the following table. The materials which may be considered wholly free from the danger of being carbonized or ignited by slow contact with pipes or boilers are printed in solid black type. Those which are more or less liable to be carbonized are printed in italics.

Substance 1 in. thick. Heat applied, 310° F.	Pounds of water heated 10° F. per hour, through 1 sq. ft.	Solid matter in 1 sq. ft. 1 in. thick. Parts in 1,000.	Air included. Parts in 1,000.
1. Loose wool	*8·1*	*56*	*944*
2. Live geese feathers	*9·6*	*50*	*950*
3. Carded cotton wool	*10·4*	*20*	*980*
4. Hair felt	*10·3*	*185*	*815*
5. Loose lamp-black	*9·8*	*56*	*944*
6. Compressed lamp-black	*10·6*	*244*	*756*
7. Cork charcoal	*11·9*	*53*	*947*
8. White pine charcoal	*13·9*	*119*	*881*
9. Anthracite coal powder	*35·7*	*506*	*494*
10. Loose calcined magnesia	**12·4**	**23**	**977**
11. Compressed calcined magnesia	**42·6**	**285**	**715**
12. Light carbonate of magnesia	**13·7**	**60**	**940**
13. Compressed carbonate of magnesia	**15·4**	**150**	**850**
14. Loose fossil meal	**14·5**	**60**	**940**
15. Crowded fossil meal	**15·7**	**112**	**888**
16. Ground chalk (Paris white)	**20·6**	**253**	**747**
17. Dry plaster of Paris	**30·9**	**368**	**632**
18. Fine asbestos	**49·0**	**81**	**919**
19. Air alone	**48·0**	**0**	**1,000**
20. Sand	**62·1**	**527**	**471**

"Professor Ordway's report is as follows: 'Careful experiments have been made with various non-conductors, each used in a mass 1 in. thick, placed on a flat surface of iron kept heated by steam to 310° F. The preceding table gives the amount of heat transmitted per hour through each kind of non-conductor 1 in. thick, reckoned in pounds of water heated 10° F., the unit of area being 1 sq. ft. of covering.

"'The first column of figures of results gives the loss by the measure of pounds of water heated 10°. The second column gives the amount of solid matter in the mass 1 in. thick. The third column gives the amount or bulk of included or entrapped air.'

"There are some mixtures of two materials which may be quite safe, although consisting in part of substances which may be carbonized. It must also be considered that a covering for a steam-pipe or boiler should have some strength or elasticity, so that, when even put on loosely and holding a great deal of entrapped air, it may not be converted into a solid condition by the constant jar of the building, then becoming rather a quick conductor. This warning may be applied especially to what is called 'slag wool,' which consists of short, very fine threads of a brittle kind of glass. The following table has been submitted by Prof. Ordway, with the following explanation:

"'The substances given in the following table were actually tried as coverings for two-inch steam-pipe, but, for convenience of comparison, the results have been reduced by calculation to the same terms as in the foregoing table.'

COVERING.	Pounds of water heated 10° F per hour, by 1 sq. ft.
21. Best slag wool	**13**
22. Paper	*14*
23. Blotting paper wound tight	*21*
24. Asbestos paper wound tight	*21·7*
25. Cork strips, bound on	*14·6*
26. Straw rope wound spirally	*18*
27. Loose rice chaff	*18·7*
28. Paste of fossil meal with hair	**16·7**
29. Paste of fossil meal with asbestos	**22**
30. Loose bituminous coal ashes	**21**
31. Loose anthracite coal ashes	**27**
32. Paste of clay and vegetable fibre	**30·9**

"'Later experiments have given results for still air which differ little from those of Nos. 3, 4, and 6. In fact, the bulk of matter in the best non-conductors is relatively too small to have any specific effect, except to entrap the air and keep it stagnant. These substances keep the air still by virtue of the roughness of their fibres or particles. The asbestos of 18 had smooth fibres, which could not prevent the air from moving about. Later trials with an asbestos of exceedingly fine fibre have made a somewhat better showing, but asbestos is really one of the poorest non-conductors. By reason of its fibrous character it may be used advantageously to hold together other incombustible substances, but the less the better. We have made trials of two samples of a "magnesia covering" consisting of carbonate of magnesia with a small percentage of good asbestos fibre. One transmitted heat which, reduced to the terms of the first of the above tables, would amount to 15 lbs.; the denser one gave 20 lbs. The former contained 250 thousandths of solid matter; the latter 396 thousandths.'

"'Charcoal, lamp-black, and anthracite coal are virtually the same substance, and Nos. 5, 6, 7, 8, and 9 show that non-conducting power is determined far less by the substance itself than by its mechanical texture. In some cases when a greater quantity of a material is crowded into the same thickness the non-conducting virtue is somewhat increased, because the included air is thereby rendered more completely fixed. But if the same quantity is compressed so as to diminish its thickness, its efficiency is lessened; for the resistance to the transmission of heat is nearly—though by no means exactly—in proportion to the thickness of the non-conductor. Hence, though a great many layers of paper—as in No. 23—prove to be a tolerably good retainer of heat, one or two layers are of exceedingly little service. Any suitable substance which is used to prevent the escape of steam-heat should not be less than an inch thick.'

"'Any covering should be kept perfectly dry, for not only is water a good carrier of heat, but it has been found in our trials that still water conducts heat about eight times as rapidly as still air.'"

PIPE-CUTTING AND THREADING MACHINES. *Forbes' Die Stock.*—Figs. 1 and 2 illustrate the front and back views of the Nos. 1 and 1½ Forbes' die stocks, made by Curtis & Curtis, of Bridgeport, Conn. One set of dies is supplied with the machines for each of the standard threads cut, so that only six sets of dies are necessary for threading the sixteen different sizes of pipe included in the range of the No. 1 machine, and three sets for the nine sizes of the No. 1½ machine. The dies are set by turning the face-plate to the proper graduation, and any variation in the fittings may be allowed for,

FIG. 1.—Forbes' die stock.

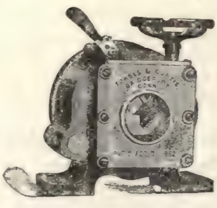


FIG. 2.

and the pipe cut either over or under standard size, by making the proper allowance at the graduation. When the dies are set to the proper size, the pipe is inserted through the self-centring vise at the back, with the end to be threaded against the back of the dies, and is clamped and brought central with the dies by turning the hand wheel shown on top of the machine. The crank is then put on to the square end of the pinion, shown in front of the machine, and through it the power is transmitted to the die-carrying gear; as the die is thus revolved a very slight pressure on the lever, shown on top of the machine, causes the gear to recede into the shell and the dies are fed on to the pipe. When the thread is cut to the required length, the machine is run backwards for about one turn, so as to take off any burr that the dies may leave; the dies are then drawn back and the pipe is removed from the machine. The depth of the shell allows a thread to be cut about twice the standard length, and if a still longer thread is desired, it can be cut to any length by loosening the vise and pulling the gear, with the pipe still in the dies, forward, so as to give it a new start as many times as is required. Fig. 3 shows a heavy power pipe-cutting and threading machine on the same principle. The vise for holding the pipe is self-centring, and the dies are opening and adjustable to any variations of the fittings.

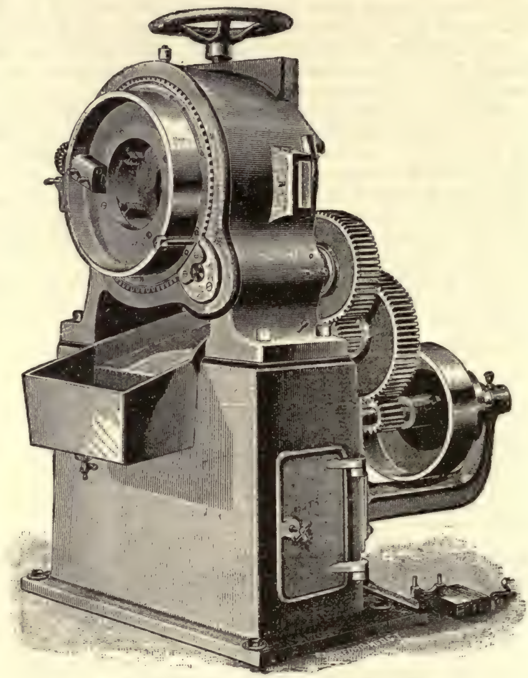


FIG. 3.—Curtis' pipe-threading machine.

Pipe-threading Attachment for Lathes.—Fig. 4 shows an attachment which can be attached to any lathe, within certain limit of size, and with which a lathe can be turned into a power pipe-threading machine in a few minutes, and pipe of any length threaded very rapidly and correctly. This attachment consists of a die-carrying head, attached to the spindle like a chuck; an adjustable, self-centring vise attached to the carriage, and an adjustable pipe rest, attached to the bed of the lathe, to support long lengths of pipe, as shown by the heavy engraving in the accompanying illustration. The pipe is held securely by the vise on he carriage and fed to the revolving dies by moving the carriage. This can be done automatically by setting the lead screws of the lathe to cut the number of threads corresponding to standard of pipe to be cut. When the thread is cut to the length required the dies can be opened by turning the face plate, and the pipe taken out without running back. All the dies are made adjustable to any variation of the fittings, and they adjust from one size of pipe to another, so that each set of dies threads several sizes of pipe without changing.

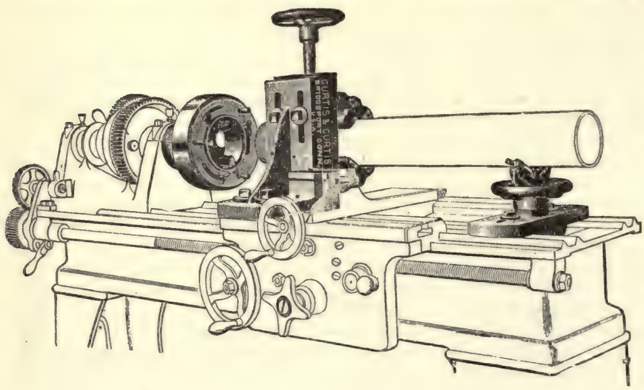


FIG. 4.—Pipe-threading attachment for lathes.

Saunders' Pipe-cutting and Threading Machine.—Fig. 5 shows a pipe-cutting and threading machine made by D. Saunders' Sons, Yonkers, N. Y. It may be run either by hand or by belt. It is arranged so that pipe can be threaded and afterwards cut off, without removing any part of the machine. It is capable of cutting off and threading pipe up to 4 in. diameter, admitting the use of either solid or adjustable expanding dies. The cutting-

off arrangement is fastened to the face of the large driving gear, between the gear and the die, in such a manner that either may be used without one interfering with the other. On the face of the large gear are ways for slides which hold V-shaped jaws of steel which are closed on the pipe by a right and left screw, which adjusts the pipe to the centre of die; also steadies it when being cut off. The cutting-off arrangement is provided with a ratchet and pawl, and a short lever which projects through an opening in the gear, and twice in each revolution comes in contact with a trip, which causes it to feed the cutting-off tool, thus securing an automatic feed. There is provided a universal gripping chuck on back end of the machine for holding pipe, to which is attached a threaded sleeve which engages with a ring having threaded sections in it, these sections being movable by a lever, so as to be engaged with the threaded sleeve or not, as desired. Thus large pipes are forced into the dies at the proper rate.

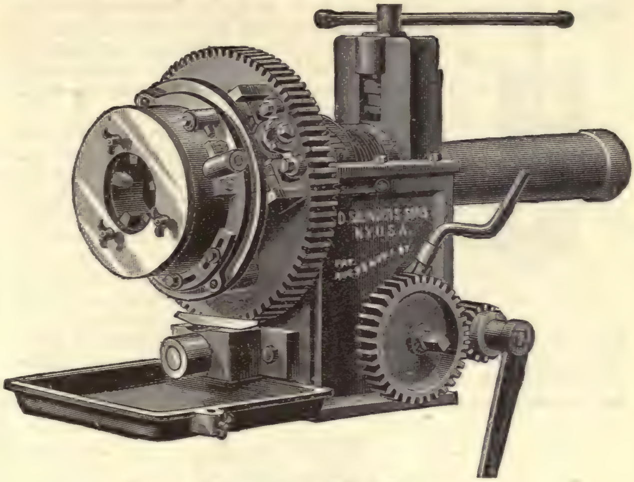


Fig. 5.—Pipe-cutting and threading machine.

Saunders' Adjustable Expanding Die is shown in Fig. 6. It is designed to be attached to any of the ordinary pipe-threading machines in use for threading steam and gas pipe. The distinguishing features of these dies are the arranging of the die-block or head with a number of sets of chasers all fitting into the same, to thread the different sizes of pipe. The head is adjustable and expanding, the thread being cut in once passing over; when the thread is cut to the desired length, the cutters or chasers are opened by a movement of the worm, and the pipe released without stopping or reversing the motion of the machine. One set of chasers can be withdrawn and another set inserted in a few minutes ; and adjustment to size is readily effected. These dies do not require to be moved from their place while cutting off the pipe, as they expand to allow the pipe to pass through into the guide in the cutting-off head of machine. The chasers can be taken out and sharpened by grinding; when too much worn they can be recut and used again, which operation can be repeated several times.

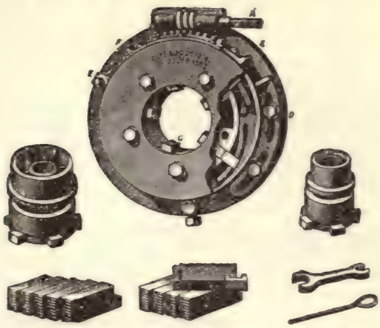


Fig. 6.—Adjustable expanding die.

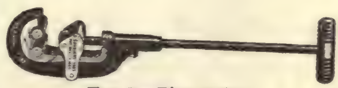


Fig. 7.—Pipe cutter.

Saunders' One-wheel Pipe Cutter is shown in Fig. 7. The body is provided with rollers for the pipe to rest on, producing a rolling instead of a sliding motion, thereby lessening the friction on the pipe. They also roll down the burr that is raised by the wheel in cutting the pipe. The hinged block with the cutter wheel is so arranged that it will not become detached and mislaid. Saunders' Three-wheel and Roller Pipe Cutter is shown in Fig. 8. It will cut off pipe without revolving the entire circle of the pipe, thus enabling workmen to reach contracted places otherwise inaccessible, such as against the wall, between floors, or in ditches. Saunders' Pipe Vise is shown in Figs. 9 and 10. In the ordinary pipe vises in use the jaws are so enclosed on all sides that the pipe can only be entered endwise, making it necessary to reserve a space beyond the vise equal to the

Fig. 8.—Pipe cutter.

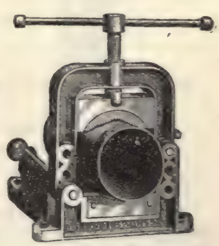


Fig. 9.—Pipe vise.

length of the longest pipe to be screwed. In the improved vise, the top half being hinged, can be opened, admitting the pipe sidewise, and saving about half the room that would be otherwise required. This side opening is attended with a further advantage—that the vise may be used for holding pipes while elbows, tees, or other fittings are screwed upon one or both ends, or for taking apart old pipe work in which the parts have become rusted together.

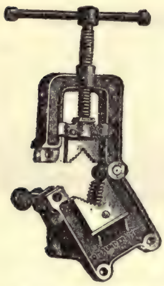


Fig. 10.—Pipe vise.

Hubbell's Tapping Machine.—A tapping machine for tapping water, steam, and gas mains, under pressure, shown in Fig. 11, consists of a case or box adapted to be applied to a main, containing a sliding carriage holding a combined tap and drill, and a stud for screwing the corporation cock into the pipe. The carriage is placed in the machine so as to have an equal pressure above and below, and is adapted to be moved by a rod from the outside of the case, so as to bring either the combined tap and drill or the corporation stud under a socket wrench or actuating spindle, projecting into the case and operated by a handle at the top, as shown in the cut. The spindle is forced down by the action of a sleeve, outside screw threaded, and passing through a yoke, upon a collar fastened to the said spindle, the yoke being held in position by two studs or posts projecting from the case or body of the machine.

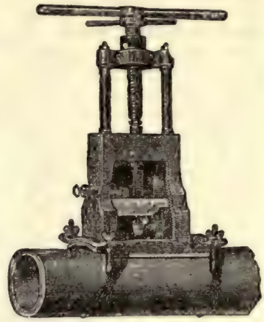


Fig. 11.—Tapping machine.

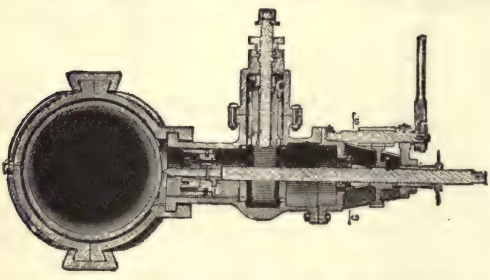


Fig. 12.—Connecting branch sleeve and tapping apparatus.

Smith's Tapping Apparatus.—Fig. 12 is a sectional view of a machine for tapping water and other pipes under pressure, and connecting branch sleeves, gates, etc. The mandrel or cutter shaft is shown run in and the central drill and tap in position to begin work. After the drill and tap have completed their work of drilling and tapping a small hole in the centre of the piece to be cut out, the main cutting tool cuts its way through the pipe. When this operation is completed, the cutting mechanism, carrying the circular piece cut from the main with it, is run back outside the gate, which is then shut down or closed. Then the tapping machine is removed, leaving the hub end of the gate ready to receive the spigot end of the pipe that is to be carried wherever required.

PIPE HEADS. Exhaust-steam pipes from non-condensing engines, leading out into the open air, and discharging above a roof, are apt to be a nuisance from their discharging with the steam fine particles of water and oil. To entrap this water and oil, and prevent its being discharged on the roof, exhaust pipe heads are used, two forms of which are shown herewith. In that shown in Fig. 1, *A* is the exhaust pipe; *B B*, branches of the same; *C*, sleeves; *D*, condensing chamber; *F*, deflector; *G*, escape; *H*, top; *K*, waste or drip.

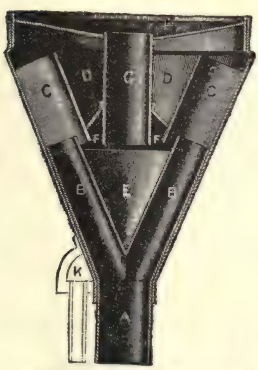


Fig. 1 —Exhaust pipe head.

In the form shown in Fig. 2 the steam is given a whirling motion by spiral passages, and the centrifugal force causes the particles of water and oil to be driven outward against the shell, whence they drain into the drip pipe, while the steam is discharged through the internal pipe.

Fig. 2.—Exhaust pipe head.

Piping of Ingots: see Steel.
Pistols: see Fire-arms.
Piston Valves: see Engines, Marine.
Planer: see Grinding Machines, Planing Machine Metals, and Wheel-making Machines.

PLANING MACHINES.—METAL. *The Sellers Spiral-gear Planing Machine.*—At the Paris Exhibition of 1889 Messrs. William Sellers and Co., Incorporated, of Philadelphia, exhibited a planing machine, Fig. 1, which attracted great attention on account of the many

interesting features which it possessed. For some years it had been tried experimentally in the works of the makers, but this was the first time that such a machine had been shown in public. The problem which the inventors, Mr. William Sellers and Mr. John Sellers Bancroft, had set themselves to solve, was to design a planing machine which would turn out work without any evidence of jarring or "chattering," so that it could be used without scraping or polishing, and yet present a good surface. In other words, they sought to give planed surfaces as good a finish as those from the lathe. They had also other subsidiary objects. Among these was the attainment of a greatly increased rate of travel on the back or idle cut; the ability to render the table self-stopping at the end of its stroke; to provide means for controlling the direction of the table movement and the operation of the feeds upon both sides of the machine; to effect the operation of the feeding and tool-lifting devices at a uniform speed, whether the table was moving in one direction or the other, and while the table was at rest.

To prevent a chattering motion being given to the table, the use of ordinary spur and bevel wheels, gearing into each other, is abandoned altogether. In place of them there are used pinions having the contact surfaces of their teeth arranged spirally around the axis. One such pinion gears with a straight-toothed rack on the table, its axis being inclined to the axis of the table at the necessary angle, while another on the pulley shaft gears with a straight-toothed wheel on the axis of the first pinion. The angles of the teeth of the pinions are such that the pulley shaft lies parallel with the table. By means of this system of gearing motion is communicated to the table without shock or jar, and the production of chatters is avoided. To gain a greatly increased rate of travel on the back cut, as compared with the forward cut (in the machine illustrated it was 8 to 1), the part subject

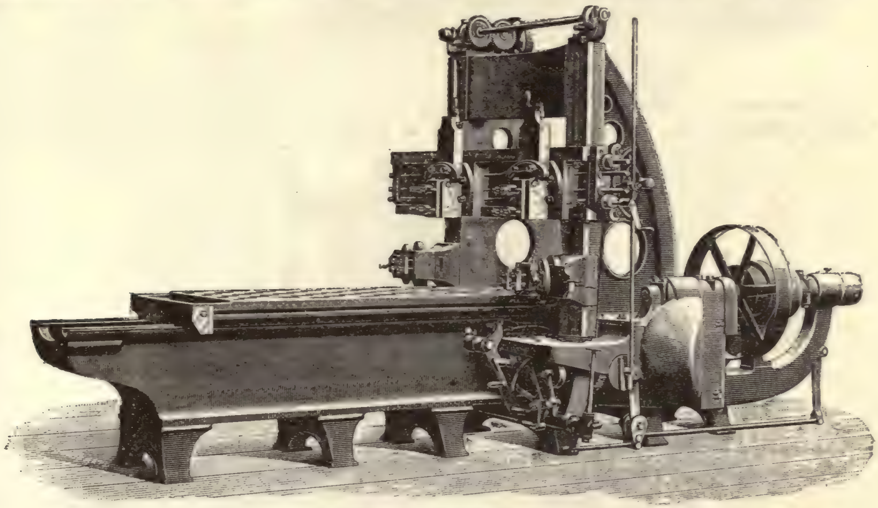


FIG. 1.—The Sellers planer.

to reversal at high speed is kept as light as possible. The pulleys run always in the same direction, the reversal being effected by a clutch between them, which engages alternately with each. The table, the pinion shaft, and the clutch shaft are the parts which suffer reversal; the first two move at comparatively slow speeds, while the latter is kept as light as possible, and special means are provided for absorbing its momentum. When the table strikes the stop at the end of its stroke, it draws the clutch out of engagement with one pulley, and presses it lightly against the other, which is, of course, running in the opposite direction. In this way the pulley and pinion shafts are quickly checked, and the table moves forward, in relation to them, so far as to take up the backlash of the teeth, with the result that when the pulley shaft is reversed there is no jar. The reversal of the pulley shaft is not directly effected by the contact of the stops on the table with the tappet levers. All that is done by them is, first, to knock off the driving power, and to apply the brake, and simultaneously to set in gear an escapement motion by which certain wheels and a cam are made to give a semi-revolution and nothing more. The cam compresses a spring which bears on the reversing clutch, and forces it to engage firmly with the pulley against which it has been running in light frictional contact; the wheels put on the various feeds, which thus occur between the end of one stroke and the commencement of the next. By an ingenious device on the hand lever at each side of the machine, the escapement motion can be thrown out of action, and then, when the stops meet the tappet levers, the machine stops, and no feed takes place. At the Paris Exhibition, 1889, the machine was run at 18 ft. a minute for cutting, and 144 ft. a minute on the return stroke.

The Hendey Planer.—Fig. 2 shows a planing machine made by the Hendey Machine Co., of Torrington, Conn., which embodies many new improvements. The table receives back

and forward motion from an open and cross belt, through a powerful train of cut-gears and rack. The proportion of belt speed to speed of table is 44 to 1, and one belt shifts before the other. The feed is obtained by an oscillating disk controlled by stops, and is adjusted by worm and worm-gear. The up-and-down feed can be operated from either end of the cross head.

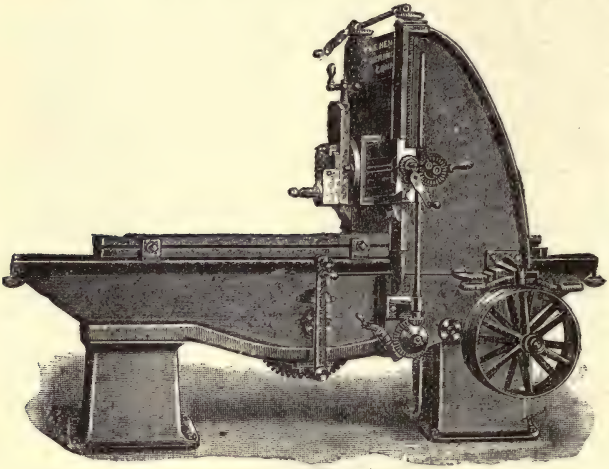


FIG. 2.—The Hendey planer.

OPEN-SIDE IRON PLANERS.—The open-side planer is in no sense a "special" tool, as it does the same work as the ordinary two-post planers of equivalent size. A comparatively small "open-side" tool will, however, plane work which would necessitate a larger planer of the regular style.

To drive these planers, the builders use the Sellers' spiral planer motion. The cross beam is supported by a brace rigidly bolted to back of post. This post is well and heavily proportioned, and is amply strong to overcome any strain. The post takes a bearing on the bed equal in length to $1\frac{1}{2}$ times the amount of overhang of beam.

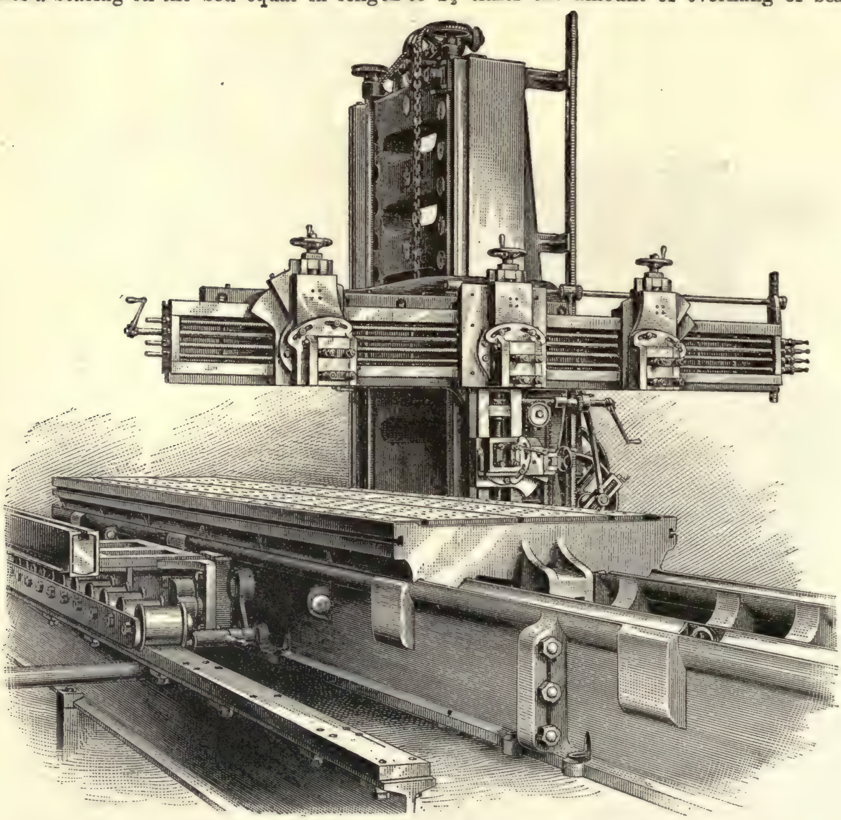


FIG. 3.—Open-side extension planer.—View showing outer post removed.

The head on the beam has automatic feeds in all directions. The beam and cross rail are raised and lowered by power. The builders claim that there is less vibration at end of

the beam of this machine than there is in centre of the beam of a two-post planer. The Open-side Extension Planer, built by the Detrick & Harvey Machine Co., is shown in Fig. 3. This style of planer differs from the standard open-side planer in that it has an outside post and long beam. This post is adjustable on an extension bed to and from the platen. Both side heads can be used simultaneously on a wide range of work varying in width, while the long beam gives a corresponding range of travel to the horizontal heads.

If it is desired to use the machine for work which will not pass between the posts at their extreme limit, the outer post may be entirely removed, and by running the beam back in its housing, the tool is converted into a standard open-side planer, as represented. The general design of extension planer is similar to the standard open-side machine, except that certain parts are made heavier to meet the increased capacity, and to accomplish the additional work which it may be called upon to perform. With these planers can be furnished an attachment designed for planing segments. In this case the beam heads are removed and placed on arms, which are swivelled from main saddles to side saddles. The

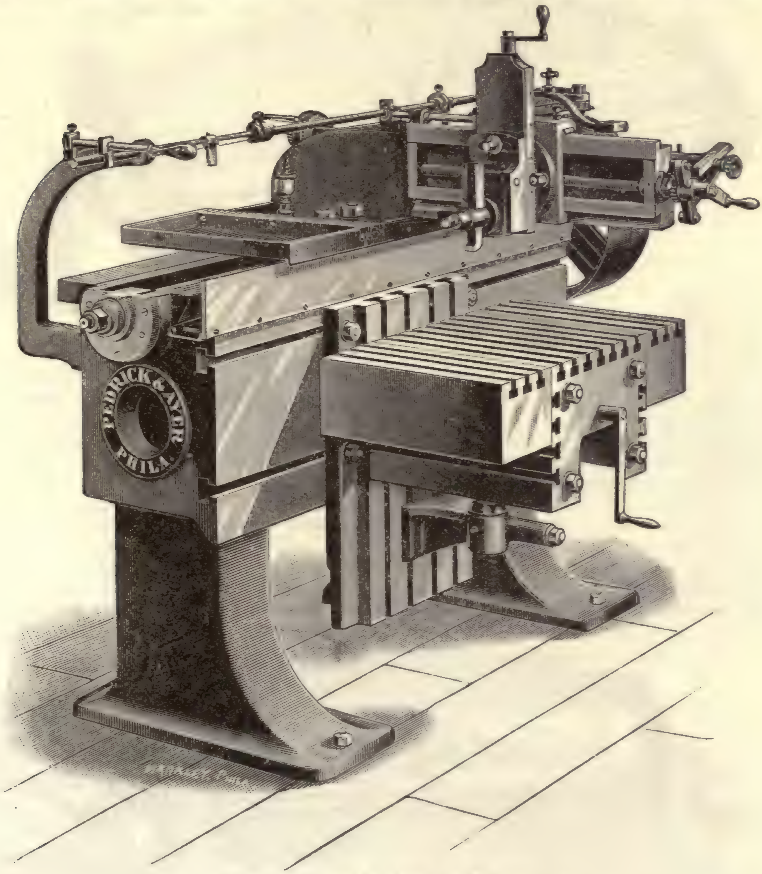


Fig. 4.—Open-side planer and shaper.

heads with automatic feed can then be used for planing angles on segments. When once set at desired angle, any number of segments can be planed uniformly and accurately. A centre head on the beam may be used simultaneously with above to face off the joints of the segments. The *Iron Age* of July 16, 1891, describes one of these planers built for the Walker Manufacturing Co., of Cleveland, O., for planing the segments of large pulleys and sheaves (its size being such that all the segments, even of the largest wheels, can be planed at one setting), as follows: "The machine will plane 120 in. wide, 96 in. high, and 25 ft. long. Combined with great capacity and ability to do work 10 ft. wide, the tool is adapted to perform work of half that width as economically as a 60-in. planer. The planer is triple geared, which reinforces the already powerful spiral gearing, and makes the tool capable of taking several heavy cuts simultaneously. The width of the table is 60 in., and depth of the same through the Vs 14 in. Bearing on the V-ways each side is 11 in. The depth of bed, 24 in. The worm has an axial pitch of 10 in., is 16 in. long, and engages in a rack having a width of 9 in., and $2\frac{1}{4}$ in. pitch. The cross heads each have an 18-in. bearing on the beam, and the side heads a 15-in. bearing. The vertical travel of the main head is 14 in., while that of the

side heads is 9 in. The bevel driving gear and pinion have a 7-in. face and $1\frac{3}{4}$-in. pitch. The weight is 140,000 lbs."

The Richards Open-side Planer and Shaper.—Fig. 4 shows a 36-in. open-side planer and shaper built by Pedrick & Ayer, of Philadelphia. The construction and general arrangement of parts in this machine are somewhat different from the usual style of planers and shapers. The sliding head and cutting tool are supported by an overhanging or extended arm, moving parallel with the slotted side of bed, and the work to be planed remains stationary, being fastened to the plates or tables as may be required. The open side permits the planing of large and difficult pieces, and as they remain at rest while being planed, they are easier to set and fasten than they would be upon a moving table or platen. The saddle is moved by means of a screw and pulleys, with shifting belts, and has a quick return. For some classes of work, these open-side planers have advantages over the ordinary style of

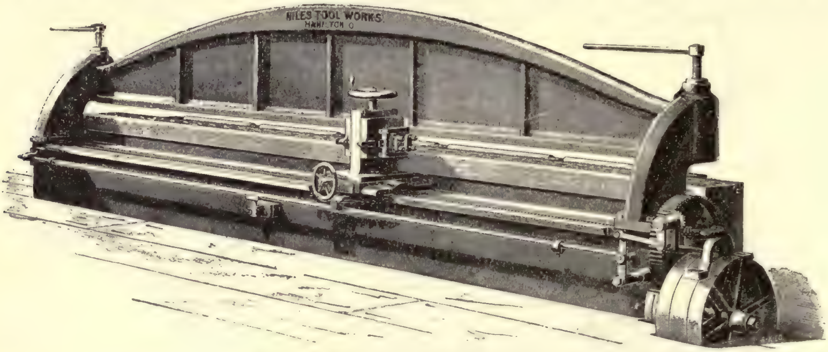


Fig. 5.—Boiler-plate planing machine.

planer. Among them are the following: The tools move over the work, which is fixed. Large pieces and small ones are planed at the same speed. There are flat surfaces, horizontal, vertical, and parallel for mounting work, so pieces of any shape can be fastened at once. The shifting motion is such that the tools stop with the same accuracy as in a shaping machine. By removing the tables, work of any kind can be planed. Pieces of 10 tons weight have been planed on a 30-in. machine. The heaviest machines can be used for shaping, and run with a 2-in. stroke, without shock or jar.

Plate-planing Machines.—*The Niles Boiler-plate Planing Machine.*—Fig. 5 shows a boiler-plate planing machine, made by the Niles Tool Works, Hamilton, O. It will bevel the edge and square up a narrow caulking surface, plane plates 14 to 18 ft. long at one setting, and is arranged to plane any length by resetting the sheet. There are two separate tools on the tool post. The cut is taken both forward and back. A large steel screw oper-

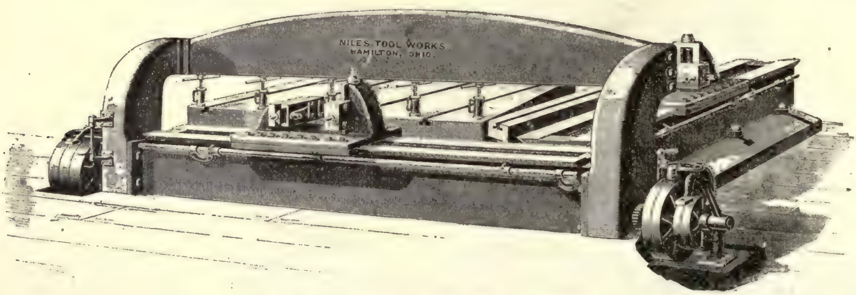


Fig. 6.—Double plate-planing machine.

ates the saddle. Brackets extend out from the back of the bed, carrying rollers for supporting the sheet and facilitating handling. A heavy clamping bar holds the plate securely in position. The bar is raised and lowered by screws at each end. No intermediate screws are required, hence the operation of setting is quickly accomplished. The driving pulleys are 24 in. diameter for a $2\frac{1}{2}$-in. belt, and strongly geared to the screw. The screw is of steel, $3\frac{1}{2}$ in. diameter, 2 in. pitch, and is supported in a continuous bearing, preventing sag or deflection. The nut is of extra length and surrounds three-fourths the diameter of the screw.

Double Plate-planing Machine.—Fig. 6 shows the Niles double plate-planing machine, which is designed to plane on two adjoining edges of plates at the same time. When plates are to be squared or planed to bevel shapes it is of great convenience to be able to do this at one setting of the plate. In the single plate planers, when work is to be planed on the end,

the plate must be set by reference to the edge of the table. If the sheet is long and narrow, and is to be planed to any other angle than 90°, the setting becomes a difficult matter if any degree of precision is required. These difficulties are obviated by the use of double plate planers, and at the same time the work is performed both quicker and better. The front, or long side, of this machine is similar in construction to the single machines. It has a tool carriage 54 inches long, driven by a heavy steel screw, and carries two tool heads for cutting in both directions. One of these heads has compound and angular movement, as in ordinary planers, while the other has horizontal movement only. The end bed is pivoted at the right-hand of the front bed. It is clamped to a heavy T-slotted sole plate, and can be adjusted 10° either way from a right angle by means of a rack and pinion. In this movement the bed carries with it a T-slotted table for holding and clamping the end of the plate. The tool carriage is driven independently in the same manner as the front one. It has one tool head only, with compound and angular adjustment. It cuts in one direction only and has quick return. The clamping bar is a heavy box girder rigidly secured to box housings bolted to the long bed. The housings are overhanging, so that plates of any length may be planed by resetting. The clamping bar is placed at sufficient height to clear the end tool slide, and the work is held by screw jacks. A wide T-slotted table is placed at the back of the machine, suitable for holding large plates without the aid of auxiliary tables. Each tool carriage is driven and operated independently, except that a safety belt-shipping device is provided, by means of which the front tool carriage reverses the motion of the end carriage whenever there is danger of a collision between them.

Rotary Planers.—Figs. 7 and 8 show two forms of rotary planing machine, made by the Betts Machine Co., of Wilmington, Del. These machines are specially designed for facing plane surfaces on columns, chords, etc., in iron bridge building, architectural iron work, and many other jobs where large numbers of pieces of the same kind are used; on this class of work they have advantages over reciprocating planers; in many cases the finished work can be removed and replaced by new work while the machine is still facing at the opposite end. The cutters are secured in a heavy plate wheel, banded with wrought iron, and driven by worm and worm-wheel; this plate wheel has a heavy steel spindle and is carried in a travelling head on the bed plate, the work remaining stationary. They have

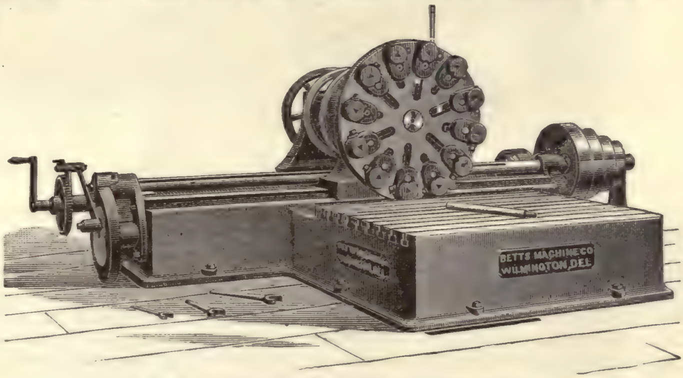


Fig. 7.—Rotary planer with adjustable cutters.

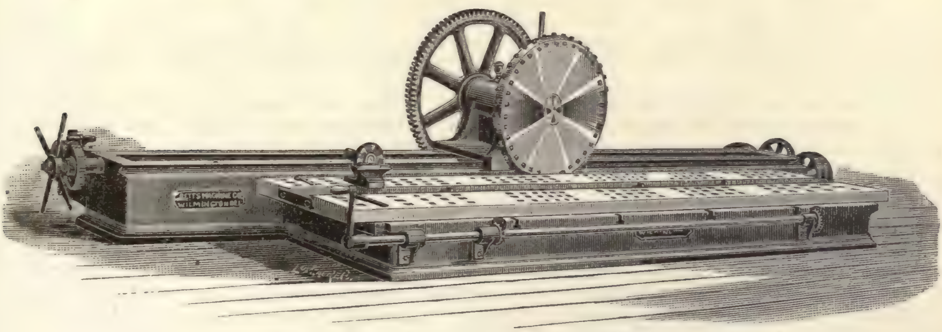


Fig. 8.—Rotary planer with movable tables.

automatic variable feeds, and the heads are moved back by an independent countershaft. In the machine shown in Fig. 7 the cutters are made adjustable. The spindles have an end adjustment, so that there is no necessity for moving the work to make the cut. These machines may have a cutter plate with fixed cutters put upon them, in place of the adjustable cutters, if so desired, and can be mounted on a turn table, and be swivelled through an angle of 90° by means of a pinion and segmental rack, the driving being so arranged as to permit this movement. This feature enables the pieces to be faced off at any

angle, and saves the inconvenience of setting the work at an angle on the shop floor, thus economizing room.

Newton's Pillow-block Planing Machine is shown in Fig. 9. It is used for planing

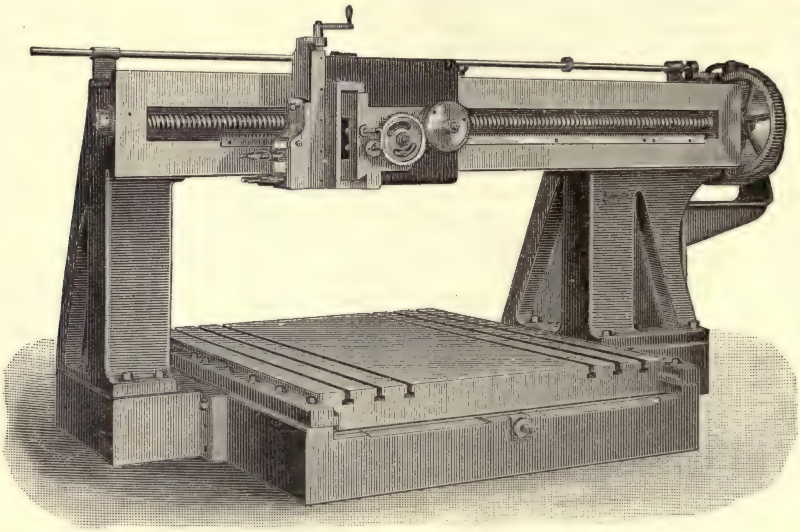


FIG. 9.—Pillow-block planing or shaping machine.

stationary engine beds to admit the brasses, and has an automatic feed both vertical and horizontal, with a range from the finest feed for roughing to a coarse feed for finishing. The carriage can be adjusted to set the work. The machine will admit work 30 in. high by 8 ft. wide.

PLANING MACHINES.—WOOD. In considering the subject of planing machinery, we may include therein machines which give to sawed timber proper dimensions, dressing it on all four sides at once, as well as those which merely give it a true surface; and as very many of those machines which dress it on from two to four surfaces, and give it its finished width, make a tongue upon one edge and a groove in the other—matching, as it is called—we must, while studying and describing some types at least of planing machines, study and describe the matching machine also.

It may be well to call attention to the fact that as regards the tools which work upon the wood, they may be held either in cylinders or in disks ; the disks being represented by merely their radii and the cylinders by mere lengthwise lines upon their periphery, parallel to their axis. Cylinder machines make cuts which are practically straight and at right angles to the length of the stick and to its direction of passage through the machine. The disk or arm machines make cuts which are practically circular arcs bounded by the edges of the stick. In the first class we consider the Woodworth and similar cylinder planers; in the second, the Daniells. Both of these are illustrated and described in a former volume of this work.

The Modern Daniells planer is built entirely of iron and steel, except the face of the table, which is made of yellow pine. This gives the machine great strength, and especially adapts it to the use of railway, bridge, and car builders, who require to take large lumber or timber cut out of wind or to reduce it to square dimensions. As made by J. A. Fay & Co., the iron frame machine, Fig. 1, has its sides cast in sections, according to the length of machine wanted. The ways on which the table moves are cast with the sides and planed to fit the slides of the table, which are continuous, and form a good bearing at all points. The table is made to travel in either direction under the cutters by a self-acting motion, and it will plane forwards and backwards. The carriage has a dog or tail-screw let into the back end of the platen, so as to come below the surface, and is operated by a crank wheel. The main spindle is properly of steel, of large diameter, and running in long bearings; the arm should be of wrought or malleable iron. The material is held down by dead weights or guide plates. The carriage has side clamps for edging up. The levers for starting, reversing, or stopping the motion of the table, with the hand wheel for raising and lowering the cutters, are all within easy reach of the operator, and the table can be moved by a hand wheel when the machine is not in operation. The feed works have three changes of feed, admitting of planing while the table moves in either direction. The rack being beneath the table, with a vertical pinion, there is no danger of lodging of shavings, nor tendency to raise the table by the force required to move it. The main driving belt is not a quarter-twist, as in the old makes ; the countershaft being attached over the machine to the building and parallel to the main shaft, thus giving a straight belt ; and the driving belt

for the cutter head acts at a right angle to the countershaft. This does away with the old vertical countershaft, and the annoyance of quarter-twist belts, and the tendency of the main belt to draw the machine out of line.

A machine by the same makers, which is a combination of the Daniells and the Woodworth planing machines, is of great utility. It is shown in Fig. 2. There is a wooden frame with iron housings or uprights for carrying the cylinder and frame. The planing cylinder is horizontal, and lipped with steel, carrying three knives and running in long bearings. It is supported in its frame upon two heavy iron standards having planed surfaces, upon which it is gibbed and moved vertically, and at an angle, to retain the driving belts at the same tension. There are on each side of the cylinder adjustable pressure rollers to hold the lumber firmly to the platen ; these rollers also being arranged that they may be lifted up so that there will be no pressure when planing dimension stuff or taking lumber out of wind. The feed rollers when not in use may be moved out of the way on planed slides. They are connected by expansion gearing, and will take in lumber up to 4 in. thick. When used for surface planing the table is placed with its end under the cylinder and pressure rollers, and the feed rollers moved into position. The platen or carriage for using the machine as a Daniells planer has friction feed works, with changes of speed, and is arranged to plane while the

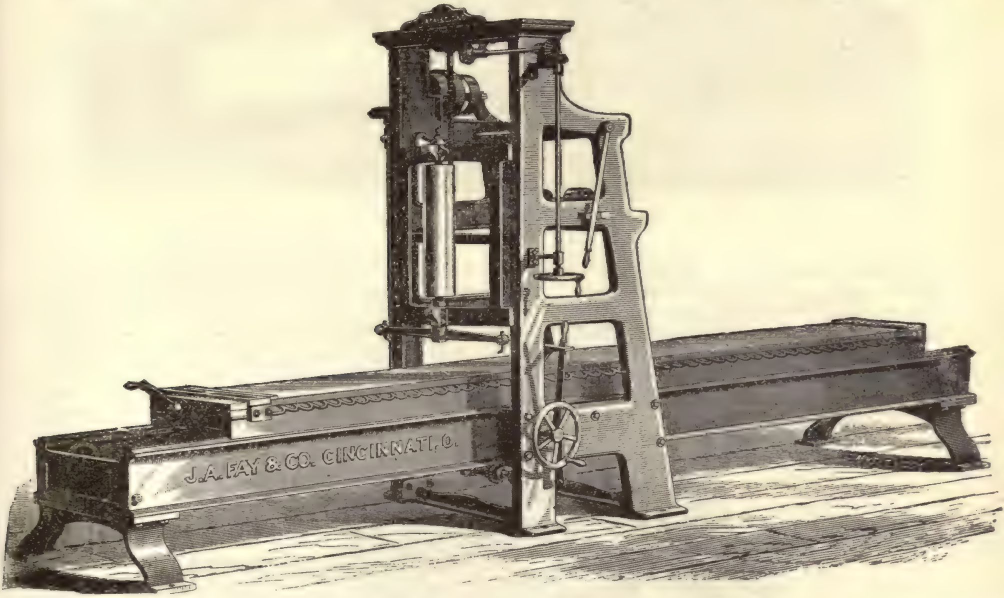


FIG. 1.—The Fay-Daniells planer.

carriage is running in either direction. The vertical adjustment of the cutting cylinder is sufficient to allow stuff up to 24 in. thick to be dressed. It will be observed that the feature of the Daniells planer which is retained is the moving carriage or platen ; the cutting being done by the knives upon the horizontal rotating cylinder, whether the feed be by rollers or by carriage. A modification of this machine dispenses with the feed rollers, but retains the pressure rollers each side of the knife cylinder ; although provision is made for the application of power-driven feed rollers, with expansion gear—and in this case the carriage remains stationary. The machine is rapidly changeable from a dimension machine to a wide surface planer.

The special peculiarity of this class of machine is that it will make a surface good enough for glue-jointing, while it will plane in either direction of the carriage, thus greatly adding to its capacity.

In some timber planers the cylinder, instead of the bed, is raised and lowered, so that a train of rolls in stationary stands may be placed at each end of the machine; and the top of these timber rolls being but a trifle lower than the travelling bed, will support long sticks while being fed through the machine. This also does away with the annoyance and delay of adjusting the timber rolls every time the size to be planed is changed.

A double-cylinder surface planing machine, made by J. A. Fay & Co., for planing two sides of material at once, has a level bed with vertical adjustment to accommodate material up to 6 in. in thickness ; a bearing roller at the front of the bed to lessen the friction of the material, and four positive feed rolls, connected by gearing, and having adjustable weights for varying the pressure. There are also delivery rolls which have spring pressure. All the rolls are encased to protect them from dust and shavings. There are two speeds of feed, each of which is stopped and started by a lever and belt tightener acting on the slack side of

the belt. The upper cylinder has a pulley at each end to enable two belts to be used; and each cylinder carries two knives. The pressure bars on each side of the upper cylinder are self-acting, the end in front rising and falling with the feeding-in rollers, and always retaining the same relative position, yet allowing the roller to yield to any variation in the surface of the material; the bar controlling the pressure after the cut of the upper cylinder being adjustable. The bar following the cut of the lower cylinder is adjustable to meet the cut that is taken.

In the 26-in. double-surfacing machine shown in Fig. 3, the cylinders are large and slotted,

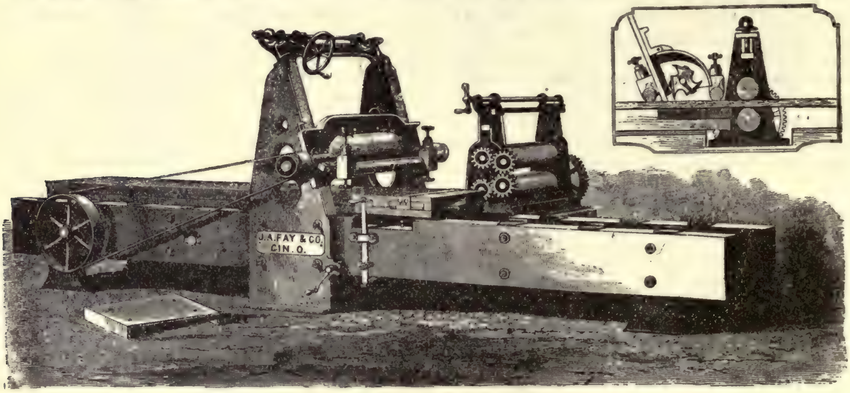


FIG. 2.—Combination planer.

and run in yoke boxes. There is a bonnet chip-breaker, and a complete set of pressure bars which have every desirable adjustment. The lower cylinder may be set for any desired cut, and the end of the bed will swing down to admit of easy access to the head for sharpening or setting the knives. The bed is raised and lowered on four screws by hand or by power; and when power is used, an adjustment of 8 in. is accomplished in one minute. When set to proper thickness, the lower cylinder, while firmly clamped to the bed, is also clamped to the sides of the frame. The gears on the feed rollers are of about double the diameter of the latter, giving great leverage. Each pair of feed-roll boxes is connected in a yoke frame to

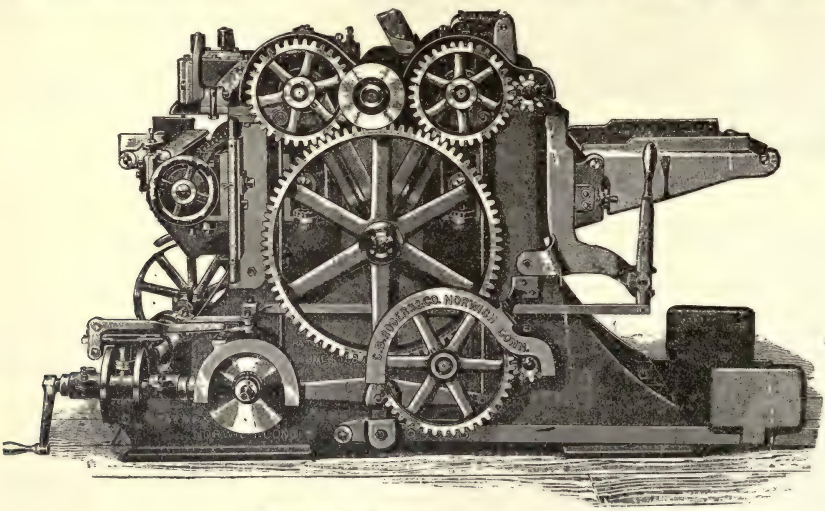


FIG. 3.—The Rogers double surfacer.

avoid the possibility of cramping, and all links are hung on boxes instead of on roll shafts. The feed is driven direct from the top cylinder, through two feed shafts provided with cones giving four changes of speed.

The Smith Double Surfacer.—In a 26-in. cabinet double-surfacing planer made by the H. B. Smith Machine Co., there are some features which are absent from some others of the same general type. Thus, for undersurfacing, the bed is supported on four screws, one under each nut of the cutting cylinder, and the curved pressure bar over the underhead is very rigid, thus giving stiffer and truer work with the undersurfacing head than would be the

case without these features. The feeding-in rolls have a weighted equalizing bar to give a parallel lift and prevent cross strain on the gears. There is a spring device to overcome the inertia of the weighted rolls when extra thick stock is being entered, and to lessen liability of breaking the weight straps or bars.

The Goodell & Waters Planer.—An 8-roll timber-planer made by Goodell & Waters, and which will surface up to 26 in. wide, and to 16 in. thick, and square timber up to these dimensions, will also, by the use of a centre guide, surface two pieces on top, bottom, and outside edge, each up to 11 in. wide, at one operation. The feed rolls are driven by a belt, passing around idlers in such a manner as to permit a greater range of thickness of material fed than is possible by gears. The second bottom roll is yielding, and weighted so as to raise and follow the irregularities of the lumber.

Flooring Board Planers.—A demand having arisen for machines with a great capacity for planing flooring boards, there has been produced a number of machines characterized by very fast feed and great capacity. Another type in which the limit of feed has not been reached, is duplex, planing and matching two separate boards at one operation, so that its capacity is from 4,000 to 6,000 ft. per hour. Its work consists in not only planing both sides, but tonguing and grooving both edges and working a bead or rabbet on both the boards. The machine has two short upper cutting-cylinders, axially in line, and two duplex sets of feeding-in rolls, also axially in line, and driven by gearing. The pressure bars before and after the cut of the upper cylinders are duplex ; and the under cylinder has also duplex pressure bars, each of which is adjustable vertically independently of the other, or both may be adjusted together. The upper cylinders raise and lower simultaneously or independently, as desired, so that the machine may be used as a duplex machine working two boards

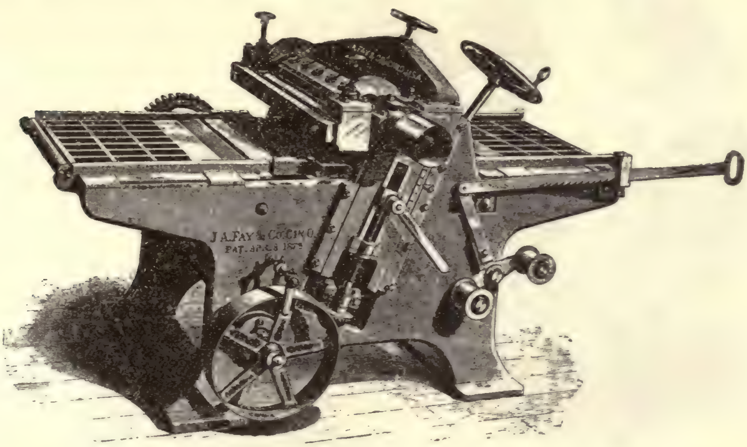


FIG. 4.—Endless-bed surface planer.

at once, or as a single flooring machine working only one board. The matching works are duplex and work the edges of both boards at one operation ; being adjustable to suit the width of lumber from the face side of the machine. The lumber platen has a duplex board guide, and an automatic edge feed for carrying the lumber to the feed rolls, moving the lumber in a straight line to the first receiving feeding rolls, even if it is warped or crooked. The feed is comparatively slow, thus making the stuff more free from cylinder marks than if capacity was got by fast speed, instead of, as in this case, by having two complete sets of cutters and working two boards at once at comparatively slow feed speed.

In some makes of fast flooring machines the beading cutter heads and matcher heads are placed between the first and the second pairs of rolls. The object in taking the beading knives from the surfacing cutter heads is to have on each head four knives instead of two, which of course helps to do rapid work. If they were put after the cutter heads instead of before them, the bead would be more apt to be ragged than if it was worked first and any trifling splintering or roughness effaced by the surfacing cutters; such defects coming out more strongly when the work is painted than while it remains uncovered. It is also claimed that when the matching heads are placed after the surfacing cutters, and the board held as firmly as it should be, to assure good matching and beading, one pair of smooth rolls cannot feed the board to or deliver it from the machine; and also that if the gauges under this arrangement are set too tight when matching, the lumber will show the marks, which is very objectionable. A properly constructed and operated flooring-board machine should deliver work at the rate of 100 ft. per minute; most of those now at work do only from 50 to 60 ft. Messrs. C. B. Rogers & Co. have brought out during 1891 a planer and matcher, to work 15 in. wide and 6 in. thick, feeding from 25 to 110 ft. per minute.

In a matching and jointing machine made by the Lane Manufacturing Co. there is an adjustable roll which holds the board firmly upon the beading head, preventing springing or

trembling while the end of the board is passing from the feeding-in to the feeding-out rolls; and the beading head is fitted with saw-teeth knives which remove fuzz from the edge of the bead.

The Fay Endless-bed Surface Planer.—A method of feeding the material in wood planers, differing from the hand, carriage or platen, and pressure-roll methods, is by an endless bed, as shown in Fig. 4. It is especially desirable for green, wet, or icy lumber; and the demand for this type is constantly increasing in this country. There is an endless apron or bed of slats driven by heavy gearing, and remaining in a fixed position at all times. The lags or strips composing it are of cast-iron, but the bearings on the ways are plated with steel. The cylinder is of large diameter, lipped with steel, and carries three knives, and pulleys for two belts. It runs in self-oiling bearings in a cylinder frame which is raised and lowered by a hand wheel. A weighted pressure bar is placed before the cut, as is also a pressure roller supplied with springs which give an elastic tension, that is controlled by a screw and hand wheel, so as to give any desired pressure. The cylinder frame carrying the cutters is gibbed to the sides. The cylinder and pressure bar adjust simultaneously to the thickness of cut, by a single movement of the hand wheel. The feed is started and stopped by a binding lever. A development of this machine, of much heavier build, for planing-mills, bridge work, etc., has a stationary cylinder so that the countershaft may be either on the floor or overhead, as desired. There is a chip-breaker for holding the fibre of the wood during the process of cutting, and a pressure roller in front weighted with folding levers so arranged that either end will work independently of the other, which is desirable on unevenly sawed lumber. This

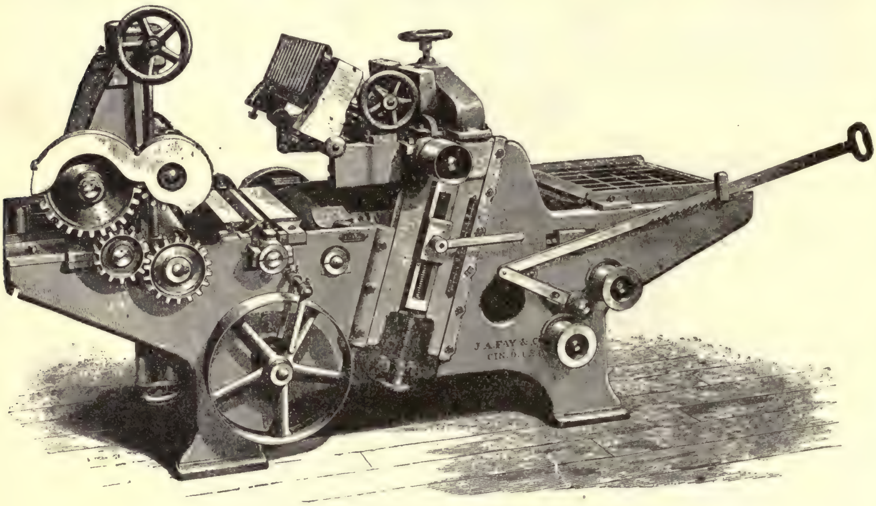


FIG. 5.—Endless-bed surface planer.

allows the rollers to adjust to the different thicknesses of the lumber without unduly straining any of the parts of the machine.

The machine shown in Fig. 5 has the line of the bed in a fixed position, the upper and the lower cylinders, and the pressure bar over the latter, adjusting simultaneously to suit the thickness of the timber. The upper cylinder carries four and the lower one three knives, and either can be raised or lowered when running. The pressure bar over the lower cylinder is hinged, and can be swung back out of the way to give free access to the cutters. There is a set of heavy delivery rollers after the lower cylinder, driven by expansion gearing, and feeding the lumber away from the machine, thus relieving the strain on the travelling bed in feeding heavy lumber. There are two speeds of feed, 40 and 60 ft. per minute. The feed rollers are broken in their length, so that either one wide board or two narrow ones of unequal thickness may be planed at once. The cylinders have chip-breakers. A uniform elastic pressure may be maintained by pressure springs. The pressure bars before the cut are sectional, one for each divided roller, and are raised simultaneously with the upper cylinder.

Other Endless-bed Surfacers.—In a machine made by the Egan Co. the heads instead of the bed raise and lower; the upper head being belted from each end and raising and lowering from the working end of the machine. Each slat of the bed or travelling apron has on the under side a circular wedge, extending between the two bearings to give stiffness; and as each end of each slat passes under a rib of the full length of the bed, it is impossible for it to lift it into the cutter head even when planing the thinnest stock. The pressure adjustment, including the two pressure rollers, is raised and lowered with the cylinder to suit the thickness of the material being planed. The lower cylinder has a pair of feeding-out rolls.

In one type of the double-cylinder, endless-bed surfacer, the endless bed itself extends

through a comparatively short portion of the length of the machine, the stock being fed to it from a plane grated table; the upper cylinder gets the first cut and the lower one next; and after the second cut there are feeding-out rolls, broken into two lengthwise portions so as to take in two pieces of different thickness. One desirable feature in this type of machine is in those made by Hoyt & Bro., in which the feed rolls and their operative mechanism are carried by a swinging bar that is easily swung away or opened like a gate, giving access to the cylinder for setting or sharpening the knives. In some machines the sprocket wheels are made to move the bed by the links; in others, by the slats themselves, which latter is by many considered preferable. In the H. B. Smith machine, instead of the pressure bar there is a roll which is held down by rubber springs to reduce friction.

Jointers.—It being next to impossible to joint the edges of wood perfectly by hand tools, for gluing, such work is usually done by machinery, both by reason of the greater perfection of surface and on account of the decreased cost. The stroke jointer is a very simple machine which, while taking up a good deal of room, is not very heavy, and is very simple in operation. There is a cast-iron table, borne by suitable legs or pedestals, and through the top of which there project two or more ordinary planing knives. Along this table there vibrates lengthwise a frame which bears the piece the under side of which is to be jointed. The material being properly clamped to the carriage, the latter is given lengthwise motion by a pitman driven from a large wheel upon a separate stand, this being operated by hand or by power, as desired.

The hand-feed planing and jointing machine will plane out of wind; and as the amount of material cut away is controlled by hand and by sight, there is scarcely any kind of planing which cannot be done by it more truly and with less labor than by hand work, and in one-tenth of the time required thereby. In the H. B. Smith Co.'s hand planer there is within the framing a chute which delivers the shavings in the rear of the machine and at the same time forms a cross wedge in the framing, thus increasing the rigidity of the machine.

A useful machine, which is a combination of power surfacing machine and hand planer, is designed to save the expense and space of two separate machines in furniture cabinets and coffin manufactories, wherever the separate machines have been found of value. The cylinder is arranged so that planing may be done either under it, by feed rollers, or over it, by hand. When arranged to do the former it will surface long and short pieces up to 24 in. wide and 6 in. thick. The cylinder has three knives arranged at an angle so as to give a shearing cut; thus, in connection with a self-adjusting pressure bar before the cut, avoiding tendency to tear in cross-grain lumber.

Heavy Planers.—It is for some reasons best for planers working on doors, sash, and other articles having the grain of the wood at different angles, that the planer head be at an angle of 45°, giving a smooth surface regardless of knots or cross-grained places in the material being worked.

The heavy planer and smoother shown in Fig. 6, and made by the Egan Co., is made by reason of the desire of sash and door makers, and others producing similar classes of work, to put their work together in sections, and plane the latter after they are put together. This of course calls for a wide planer, in order to feed the stock diagonally, to preserve the edges when planing the cross rails. There are heavily braced double or cored sides to the frame. The table, which is dove-tailed in the frame, raises and lowers in inclines by two screws and a centre hand wheel, and can be locked at the desired height. The feed consists of four large feed rolls, all driven by heavy gearing, the upper front one, which is fluted, being geared on both ends, giving it a parallel lift, and thus allowing two strips of any kind of stock to be fed through the machine. All four feed rolls are weighted. The feed of the machine is taken from the cylinder, so that if the speed of the latter increases or diminishes, the feed will vary in the same proportion. The pressure bars each side of the cylinder adjust to the circle of the head, to prevent tearing out of wavy grained or knotty stock, and chipping of the ends. By feeding the stock in diagonally instead of having a diagonal planer, straight belts may be run to the cylinder, and short stuff may be planed. Such a machine is specially adapted for planing framed stock where straight and cross-grained wood are built up together.

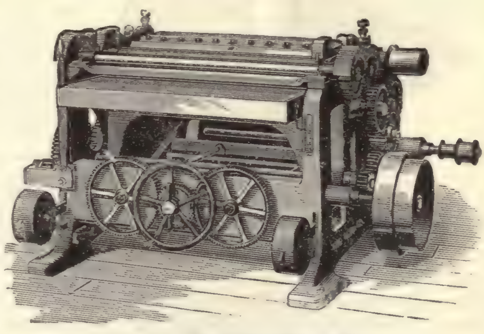


FIG. 6.—The Egan heavy planer.

Planing Clapboards.—In the manufacture of clapboards, which are so important a feature in the make-up of homes in a new country, it is usual to employ double machines, through which two boards may be passed, each of these being dressed on one side and jointed on two edges, while passing through the machine. In some of these machines the bed is stationary, and the stock fed along by rolls; in others there is a travelling body; and in yet others there is a combination of these two: there being at first a travelling bed which extends

to near the rolls, and then a short stationary bed just under the cutter head; then beyond the cutter head again there is another travelling bed for feeding out the material. Where there is roller feed there is usually one set of rolls for feeding-in and another set for feeding-out.

In designing dimension planing machines and similar tools having heavy carriages carrying large timber, it is not usually considered safe to control the carriage movement by clutches, and for such work shifting belts, or a friction feed, are employed.

Recent Improvements in Planing Machines.—In the construction of the planing machine of the present day makers seem to have arisen to the fact that such machinery should be massive in frame, and hence are giving them heavy plate sides with internal ribs ; they also plane the joints, ream the holes, turn the bolts, and in every other possible way design and construct the machine to do accurate work at high speed with heavy cut, without danger of breaking down or liability to lose accuracy of work. It is best that the cylinders of planers and matchers and surfacers be made of steel, with the spindles drawn out from the body of the forgings, leaving the cylinders and the spindles in one solid piece.

In some planing machines the lower feed rolls are double the diameter of the upper, their surface speeds, of course, being the same. It is claimed for this arrangement that it gives the lumber a better base, and causes it to enter and leave each pair of rolls with greater smoothness. In some machines the gears are always placed on the "gauge" side of the machine, and the expansion gear on the front side of the roll, so that the driving pressure will be downward and that there will be pressure on the gauge side, which is by some thought desirable.

In some machines for planing and matching, the matcher frames and spindles are dropped or swung down to change from working flooring to surfacing; in others the change is made by removing the matcher heads from their spindles, thus leaving the matcher frames and spindles always in their working position. In operating planing and matching machines, good usage recommends running the side or matcher heads against the feed, as it takes less power than the opposite way, and the cutters are kept in order longer, not coming in contact with dirt or grit which may be on the edges of the lumber. In some machines the back part of the bits, which follows and supports the cutting edge, is of circular form, to conform to the radius of the cylinder which carries them.

A decided improvement in the way of safety of high-speed planing machinery consists in casing over the gears which drive the feed rolls by a casting conforming to their outline, and of course much less likely to damage than the sheet-iron or tin casing that is sometimes used, but which is not found often enough on machines of this class.

Planters : see Seeders and Drills.

PLOWS. Since the year 1880 the improvements made in the plow of the ordinary type have concerned mainly the materials and manufacturing methods. Modifications of form have been limited to minor details, important as increasing efficiency and durability, without novelty in the general form. Cast-steel and chilled iron have been liberally adopted for the wearing parts of plow bottoms, and the advantageous skilful manipulation of these materials is naturally confined to large and costly establishments, in which alone can the forming and polishing of the mould-board be done with due preservation of the evenness of the temper and conservation of the greatest percentage of good wearing surface. The hydraulic process of "chilling" is the most pronounced improvement in the manufacture of plowshares during the last decade. It cheaply secures uniformity and exactness of contour and extreme hardness of surface. Fig. 1 shows a result of one of the applications of the process. In this instance the under skin of the metal, shown white, is chilled to extreme hardness, and the upper portion of the material left comparatively soft ; so that, in plowing, the upper face of the share wears away next the edge enough faster than the under face to yield a continuously sharpened edge of the thin chilled skin, avoiding the heavy draft of a dull share without the need of the usual frequent visits to the smith to have it sharpened. Mr. James Oliver, who has been prominent in the introduction and manufacture of chilled-iron plow bottoms, states that his first success was in using hot water in the chills, drying the moisture in the foundry flasks and preventing blow-holes. His next success was in ventilating the chills by introducing grooves along the face of the mould, which allowed the escape of the gases which form within the flask when melted iron is poured in, letting the liquid metal come in direct contact with the face of the chill and all its surface, thus removing all the soft spots in the mould-boards, and leaving the surface smooth and perfect; but that his crowning success was in the use of the annealing process, which deprived the metal of its brittleness. Malleable iron is now used for the frog of the plow. It unites the advantages of economical manufacture and "interchangeability," owing to the uniformity easily attained in malleable iron pieces, every frog fitting all plows of the same pattern in case of necessary repairs. Welded frogs or those forged from wrought-iron are liable to spring in manufacture or in use; and if it becomes necessary to supply a plow with a new land-side or mould-board an expert smith is required to fit the

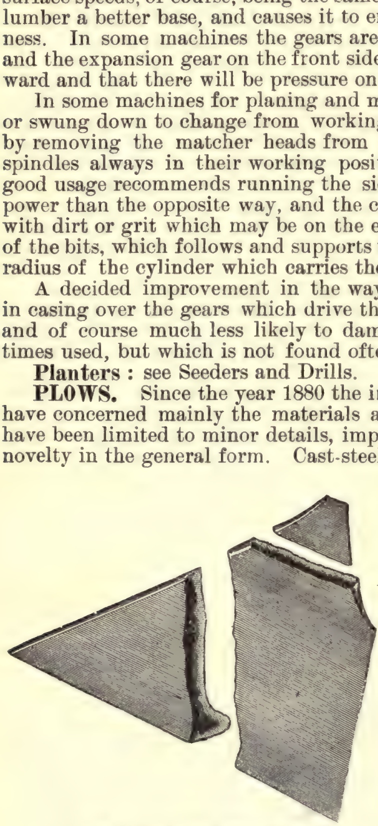


FIG. 1.—Chilled plowshare.

new parts. With the malleable iron frog an unskilled person can place the new parts with ordinary home tools. Composite metal is used with singular success for the share and breast of plows, made by superposing molten crucible steel in a layer on a red-hot malleable foundation. The ingots thus produced are used in the manufacture of shares, the inner layer of soft iron permitting the tempering of the share hard without crackling or distortion. Some of the best plows are now made from rolled plates of cast-steel highly and evenly tempered and exquisitely polished. Fine, moist earth adheres more annoyingly to a soft, low-tempered

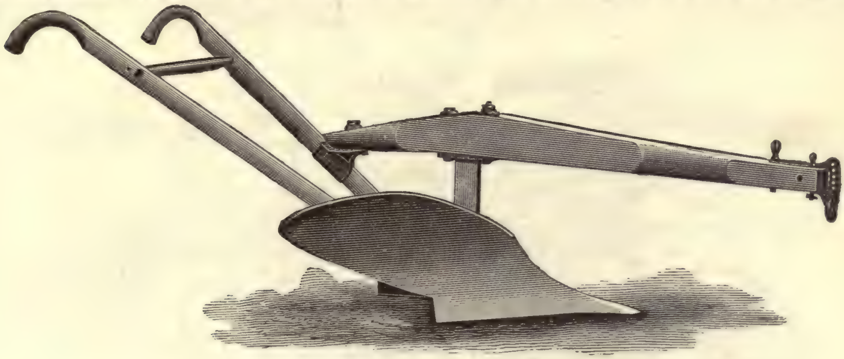


Fig. 2.—Hand plow.

than to a hard-tempered surface passing through it. The mould-board particularly should, therefore, be not only well shaped but well tempered to "scour" and prove durable. The large permanent plow manufacturing establishments now keep stocks of duplicate parts for modern-made plows, readily obtained and applied even years after the plow was made. Improvement in outline also marks the products of all the great factories, as will be evident by inspection of the modern hand plow (Fig. 2).

Deere's Riding Plow (Fig. 3) is a light, three-wheeled implement made of wrought and malleable iron and steel. The wheels are steel and carry the heel of the land-side clear of the furrow bottom, so that there is no weight except on the wheels. The swing of the tongue to

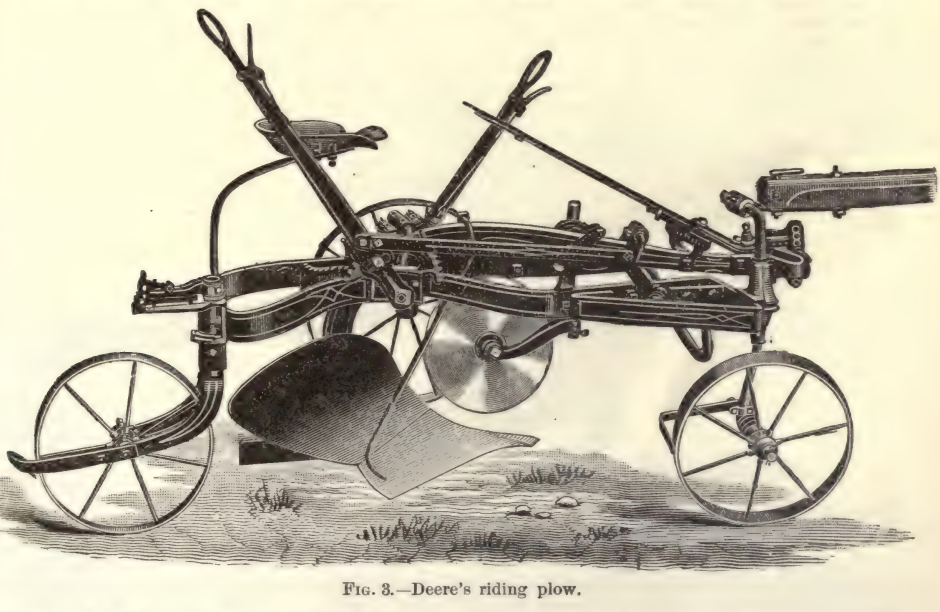


Fig. 3.—Deere's riding plow.

right or left unlocks the spindle of the rear furrow wheel, which then becomes a caster, admitting of a square turn of the plow at corners. When the horses are again straightened out this wheel returns directly aft and locks itself rigidly in line with the furrow until again unlocked by the swing of the tongue at the next corner. The plow bottom draws by a steel beam pivoted to the front of the frame, and is thus self-lining. The bottom on this class of plows can be changed to suit different sorts of plowing. In opening a furrow the front furrow wheel is lifted and held up by a suitable lever. The depth of plowing is regulated by

the left-hand lever. The amount of land taken is regulated by adjustment of the tongue slightly toward right or left by appropriate means. On arriving at a corner the end of the furrow can still be kept down to standard depth by raising the front furrow wheel slightly at the moment of turning.

Gale's Riding or Walking Plow, illustrated in Fig. 4, has three wheels with independent axles to all. One lever, connected with the land wheel by a spring, regulates the depth and insures uniform draft. This plow can run very close to fences and trees, and requires no handling at corners, and has a lever for changing the amount of landing without stopping. The rear furrow-wheel, a caster, takes away the friction from the bottom of the land-side.

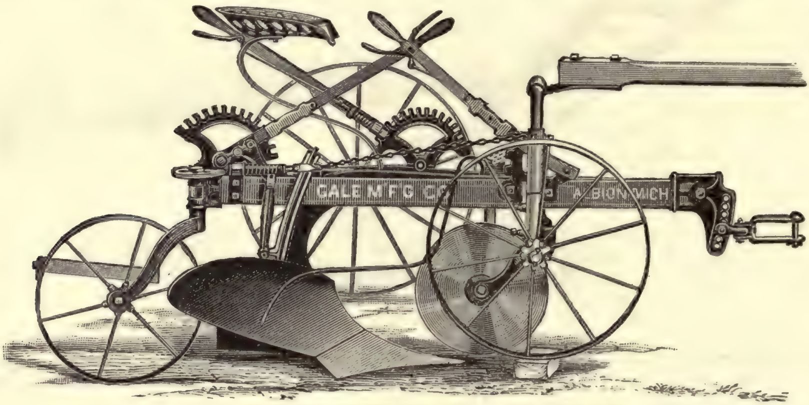


FIG. 4.—Gale's riding or walking plow.

Parlin & Orendorff's Hillside Combination Right-hand and Left-hand Plow is represented in Fig. 5. The beam is swivelled at the upright, to meet this end, giving double wear service and a more efficient action of share and mould-board than in the class of hillside plows, as formerly made, with but one bottom, shaped to run both ways.

The Canton Tricycle Plow.—The land-side is discarded in this plow in favor of inclined furrow wheels. The implement is constructed of malleable iron and steel. The inclined furrow wheels perform the function of the land-side, besides carrying weight. With the long lever the plow-point can be diverted upward to run out of the ground with a slight pressure by the operator. This same lever controls the rolling coulter and regulates the depth of plowing. The short lever adjusts the land wheel to make the plow run level at any

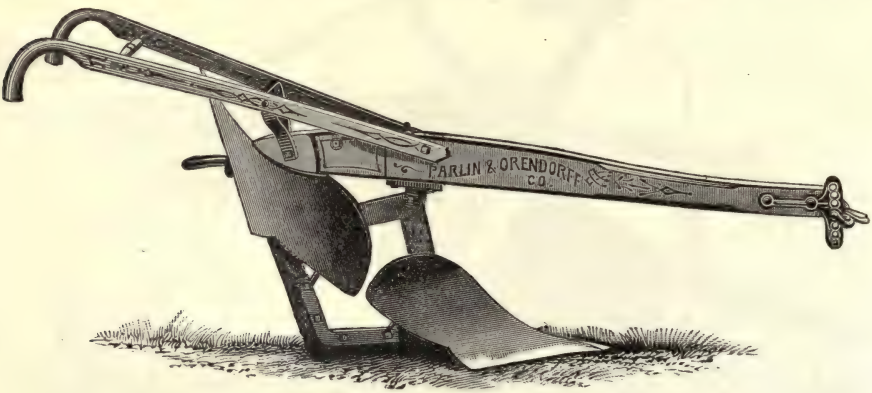


FIG. 5.—Hillside plow.

given depth. A stiff rod connects two arms, one on each furrow-wheel spindle, causing them to track by steering the rear in unison with the front wheel as the horses direct the latter by the swing of the tongue.

Deere's "Gilpin" Sulky-Plow has a self-lifting device, introduced in 1881. The setting of a lever causes the draft by the team to run the plow out of the ground. The same lever controls depth of work and levels the run of the plow by means of the arched frame with double eccentric crank axles, so that when one wheel is raised the other is lowered, and the plow and driver's seat can be kept always level.

A construction by Deere is shown in Fig. 7. Here the frame is a steel drop-forging form

ing the standard and frog, to which are bolted mould-board, share, and land-side; and the

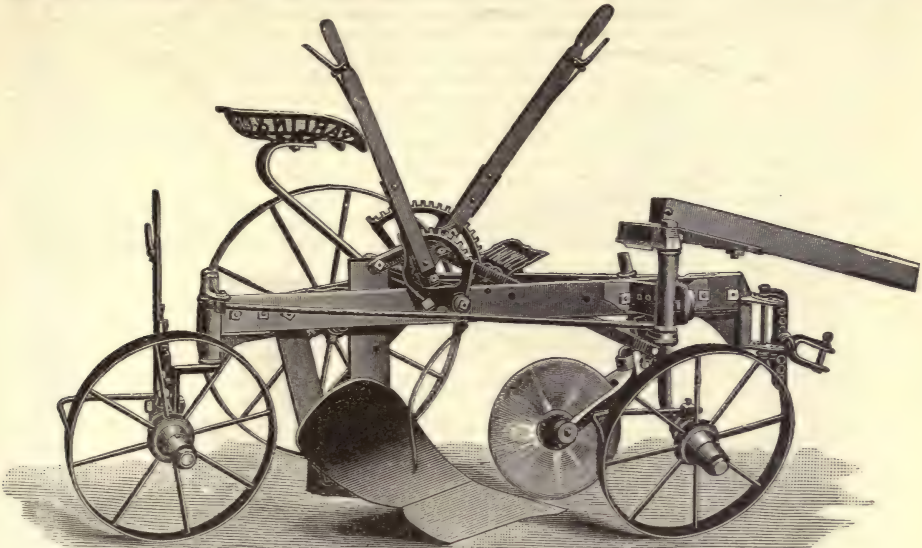


FIG. 6.—The Canton tricycle plow.

plow bottom consists of but four pieces bolted together and rigidly braced, yet with few bolts. The beam is adjustable at the butt in a slot, to control the amount of land taken, instead of

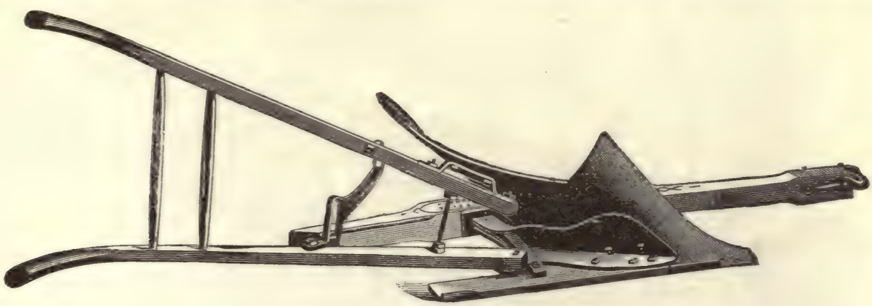


FIG. 7.

relying on the usual inexact method of setting the draft-clears at one side. The advance-mole subsoil plow (Fig. 8), is an English double-bottom implement securing deep tilth, of special advantage in root culture, now a growing interest in the United States. The subsoiler runs in advance and one furrow-width to the right of the breast-plow, which latter turns its furrow directly over upon the subsoiled strip, and the latter is never trodden by the furrow horse after it has become pulverized, the horse traversing the earth while it is yet solid. For turning headlands, or when travelling out of work,

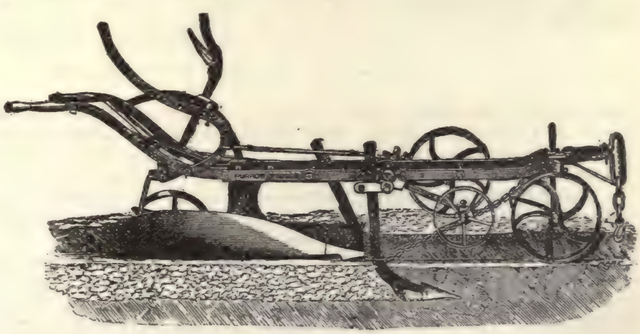


FIG. 8.—Subsoil plow.

the subsoiler swings up by a pivot and withdraws in a guiding slide under the plow beam,

by the use of a hand lever. When the lever is released a heel-claw takes the ground and instantly points the share downward into work, the strain of which is then taken by an oblique draft-chain. Peculiarities of soil and an extended scale of cultivation, particularly in the western United States, have called out changes and improvements in plows to meet these special conditions; and it is owing to these new conditions that most of the innovations have appeared. There the tough prairie soil demands special plows, and even after the turned sod has rotted, freedom from stones, and the sticky soil, make high polishing necessary in plowshares and mould-boards, and permit, moreover, the cutting of wider and deeper furrows, which is also encouraged by the level character of the land. Because of these conditions steam-plowing is exciting increased interest.

STEAM-PLOWS.—The system of drawing gangs of plows with a suitable traction steam-engine is favored in the United States and known as "the American System," to distinguish it from "the English System" of drawing the gangs of plows back and forth across the field with long cables wound on drums revolved by stationary steam-engines. This

FIG. 9.—The Price plowing outfit.

preference in the United States may be ascribed mainly to the greater length of furrow and more level character of the land in the regions of large farming operations, where steam-plowing is in course of introduction on the prairies of the great Mississippi basin, the great plateaus of the Northwest, and the wide, flat valleys of the Pacific coast country.

Fig. 9 shows the Jacob Price plowing outfit, his plowing engine drawing four gangs of three plows each at the California State Fair of 1890, made by J. I. Case, of Racine, Wis.; weight of engine, 8½ tons, the twelve plows cutting 11 ft. wide. The four gangs are independently attached to a strong, light platform running on casters, and the lifting lever of each gang is so arranged that the fireman can handle it from the run-board of the platform without descending to the ground, while going. The platform is hooked to the engine at only one point, and the whole rig is designed for lightness and strength, distributing the strains. In this class of steam-plowing the running speed is from 2½ to 4½ miles an hour, according to the character of the soil and the number of plows drawn. The bearing surfaces of the three engine wheels are extraordinarily broad in proportion to the weight of the engine, and pre-

vent sinking into the face of the ground even on soft land. On ordinary soft prairie or pasture land they leave but a faint impression. The two driving-wheels are 8 ft. high, with 26 in. of face. Large, wide wheels allow the use of numerous grouters or lugs of moderate projection, an advantage when the ground is hard and impenetrable, instead of the few but very prominent grouters requisite on the smaller traction wheels of farm engines of ordinary type.

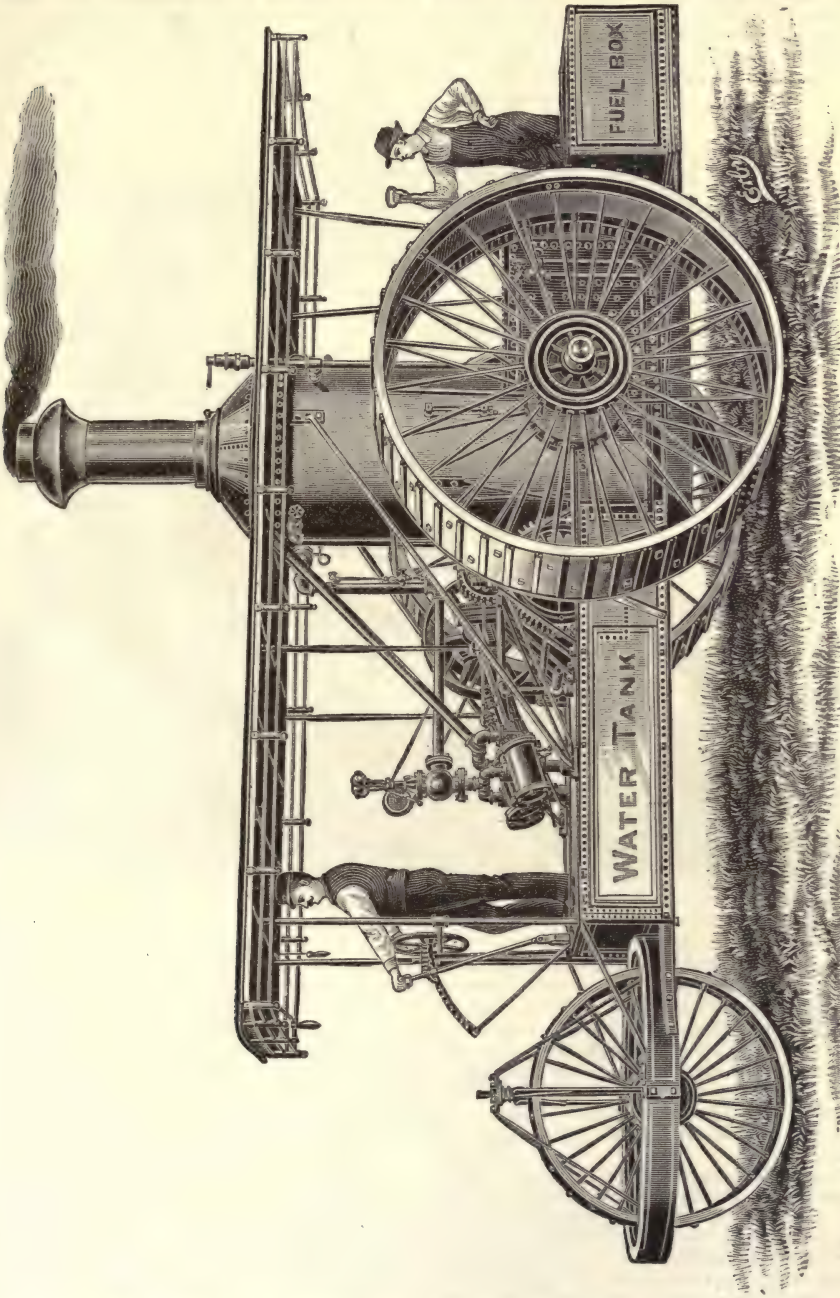


Fig. 10.—Field locomotive.

To lighten the engine, a high-pressure boiler with thick walls is used under heavy steam pressure, increasing power relatively to weight of engine and boiler as a whole, and yielding a large power available for draft in excess of the power consumed by the engine in propelling itself. Fig. 10 is a side view of the latest model of the Jacob Price field locomotive, specially designed for plowing, though available for other mobile or stationary work. It is estimated

at 70 horse-power. It performs the duty of forty actual horses in pulling, besides its self-propulsion. Driving-wheels 8 ft. x 28 in.; steering-wheel 5 ft. x 14 in.; capacity of water-tank 500 gallons; of fuel-boxes 1,500 lbs. of coal. The boiler is a combination of the upright and horizontal types, with a working pressure of 150 lbs. per sq. in., driving twin engines having piston valves. It consumes about 250 lbs. of coal per hour. Wood may be used for fuel if desired. It has two speeds, the plowing speed of about 3 miles, and travelling speed of 5 miles per hour. Fig. 11 illustrates Deere's arrangement of steam-operated plows with an ordinary farm traction engine, drawing a gang of five plows; duty, $1\frac{3}{4}$ acres of land per hour with engine geared to make a speed of $2\frac{1}{2}$ miles per hour, cutting 14-in. furrows; or $1\frac{1}{2}$ acres of land per hour if cutting 12-in. furrows. If the steering wheel of the engine is upon the

FIG. 11.—Traction engine and plows.

right-hand side, right-hand plows are requisite (and *vice versa*), to give the operator an unobstructed view of the work and enable him to preserve a uniform land. When once set, the plows require no attention for depth and land, but are thrown out and in by one lever at the ends of furrows. The outfit requires two attendants, besides a boy and team to supply fuel and water. The land should be fairly free from obstructions and in condition for plowing. Of this subject it may be stated that steam-plowing has passed the experimental stage in the United States, but is still in its early period of application. Economy and practicability are demonstrated. The introduction, though a fact, is not yet very general; but it is a mere question of time when the plowing of large areas will be done generally by power other than animal.

Plug-and-Feather Process: see Quarrying Machinery.

Pneumatic Dredge: see Dredges and Excavators. **Gun**: see Gun, Pneumatic. **Hammer**: see Hammers, Power. **Stacker**: see Threshing Machines.

Polishing: see Sash Machines, Sand-papering Machines, and Wheel-making Machines.

POTATO-DIGGER. In their present best forms these machines are of very recent development, superseding the plow type. The design is to raise the roots all to the surface, clean them from adhering dirt, and leave them in a row convenient for basketing, yet without marring their skins or bruising them.

The Pruyn Potato-digger, Fig. 1, does not turn over the earth, or roll the tubers, but raises them bodily with their earth-bed with a toothed scoop, though lifting as little matter as is consistent with obtaining all the crop. The lifted mass is delivered upon an elevator consisting of a series of transverse rods, carried by endless side-chains up the surface of

a grate inclined upward and backward, and having open slots which extend in the direction of the elevator movement. At the rear, or delivery end of the elevator, is an agitator, or separator, to sift out and drop to the ground any remnants of dirt which may have failed to screen through the elevator grate bars. The elevator speed corresponds to the speed of travel of the machine, so that the crop is lifted high enough to clean it, but otherwise virtually stands still while the digging apparatus glides beneath it, leaving it lying on the ground under which it has grown. The agitator is a row of revolving serrated disks. The rear ends of the elevated grate-bars swing freely, and thus avoid wedging and catching obstructions, and the agitator disks yield for the same purpose. The dip of the scoop is adjustable to suit various soils. A hand lever adjusts the agitator to suit conditions of work. To avoid heavy shocks, the degree of lift in the pull by the team is automatically controlled by a spring compressed under a regulating nut; thus it is claimed an access of draft lifts the scoop-point momentarily if any earth-fast obstruction is encountered, but allows it to sink again to the depth adjusted for when the obstruction is passed over, making the machine available even on somewhat stony and stumpy ground. Only chain gearing is used, placed outside the driving-wheels. No wood is employed in construction—the entire machine is of metal. The draft is communicated through two large curved side springs, to relieve machine and team from sudden jar. The machine is used not only for digging potatoes, but other root crops and for peanuts.

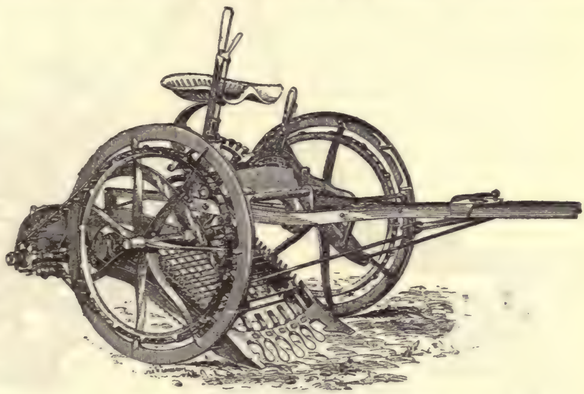


Fig. 1.—The Pruyn potato-digger.

Howard's English Root-digger, Fig. 2, has driving-wheels with prominent transverse tractor spuds on the face, and also a flange to run the wheels smoothly on hard roadways. Just over the stem of the shovel a series of forks passes in rotation, adjustable by lever, to deliver right or left. A hand lever in front regulates upward pressure on the shovel, or may be operated to throw all weight on the driving-wheels for transport, or in making turns at row ends. The operator steers the course of the machine by a tail-handle.

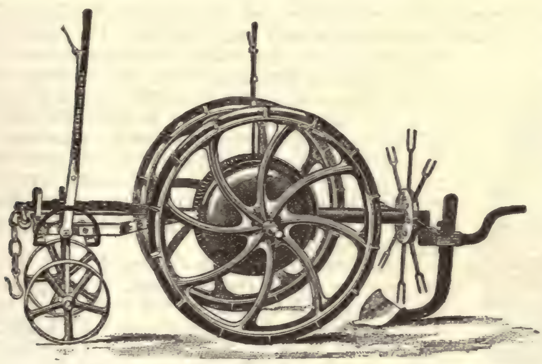


Fig. 2.—Howard's root-digger.

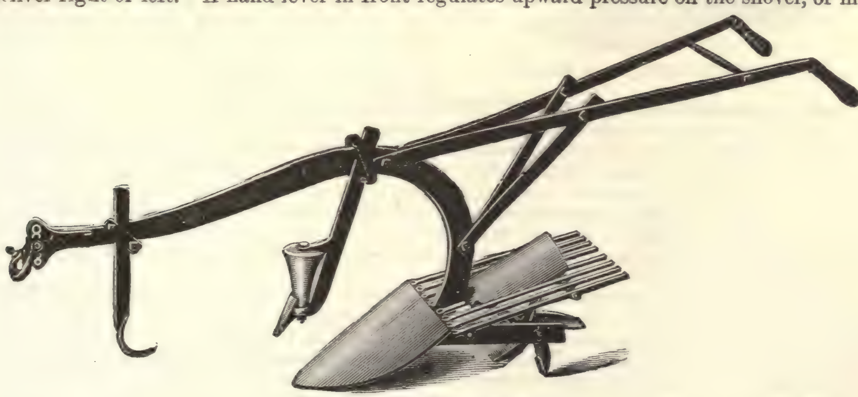


Fig. 3.—Deere's root-digger.

Deere's Root-digger, Fig. 3, depends on sifting soil from the unearthed roots between rearward, upward extending rods, agitated by a knocker-wheel which is rotated by contact with the ground.

The Hoover Potato-digger, Fig. 4, is chain geared. It elevates tubers and vines together,

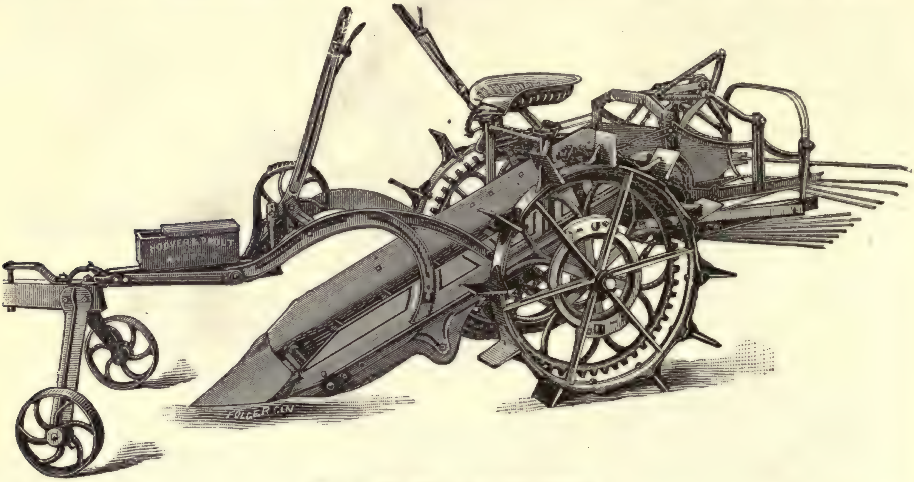


FIG. 4.—The Hoover potato-digger.

discharging the vines on the left, at the rear of the elevator, and the potatoes straight off behind to the ground. At the rear of the elevator is a back rack, having a fore-and-aft motion, to slide the tubers backward from the vines without bruising them, and it may be lowered so as to deliver them with but a slight fall. The depth of digging is regulated with a hand lever by the operator, without halting. Four horses are used. A duty of six acres or more per day is estimated. Cog gearing is to be avoided in machines of this class, since the cloud of dust produced is peculiarly wearing on such mechanism.

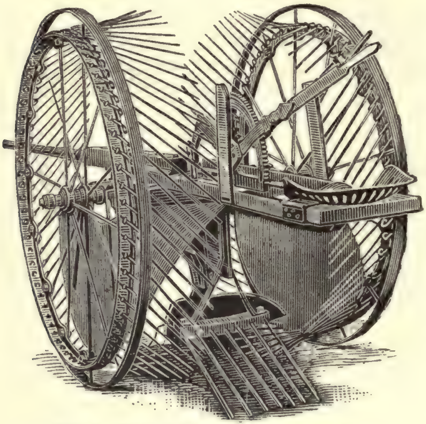


FIG. 5.—The Triumph potato -digger.

The Triumph Potato-digger, Fig. 5, has no gearing, either cog or chain, but depends on the upward motion of the two wheels at their rear part. They are armed with a rack of rods to receive the potatoes and trash from right and left mold-boards of the digging plough, and separate them by agitation of the rods. These rods are fixed oblique to an inner rim on each of the two wheels, in such a manner as to slide the potatoes into a row behind the machine. It is claimed to be suitable for two horses.

POWER, TRANSMISSION OF, ELECTRIC.—(For Hydraulic Transmission of Power, see POWER, TRANSMISSION OF, HYDRAULIC. For Mechanical Transmission of Power, see BELTS. For Transmission by Compressed Air, see AIR COMPRESSORS. See, also, NIAGARA, UTILIZATION OF.) Dr. Pacinotti, in June, 1864, mentioned the fact that his "electro-magnetic machine" could be used either to generate electricity on the application of motive power to the armature, or to produce motive power on connecting it with a suitable source of current. This, so far as can be determined, was the first mention of the now so well-known principle of the *reversibility* of the dynamo-electric machine, the practical utilization of which implies the electrical transmission of mechanical energy.

The principle of the reversibility of dynamo-electric machines appears to have been perceived by Messrs. Siemens about 1867, but it was not heard of in practical application until the year 1873, when it was practically demonstrated by MM. Hippolyte Fontaine and Breguet at the Vienna Universal Exposition. In this case a Gramme machine used as a motor to work a pump was run by the current produced by a similar machine connected by more than a mile of cable, and put in motion by a gas engine. This was the first instance of electrical transmission of mechanical energy to a distance.

Theoretical Considerations.—The work done by any electric motor is equal to the product of the current flowing through the circuit and the counter electromotive force the motor has

set up. The efficiency of transmission is as the ratio of the electromotive force of the generator, E, to that of the motor (counter E.M.F.), e, that is, efficiency $= \frac{e}{E}$. As this expression does not contain the factor of resistance of the line or machines, Marcel Deprez deduced therefrom that the *electrical transmission of power is independent of the distance of transmission.* Theoretically this assumption is correct, but in practice various factors involved make its direct application impossible. According to M. Deprez, in order to obtain the same useful work, whatever be the length of the line, it suffices simply to vary the electromotive forces of the machine proportionally to the square root of the resistance of the circuit. In other words, if R represents the resistance of the circuit, and E and e, respectively, the electromotive forces of the machines, and in such a circuit we obtain useful work at the motor w, then, in order to obtain the same amount of work with other values, R^1, E^1, e^1, it is necessary to make the new values E^1 and e^1 such that they will satisfy the following equations:

$$\frac{E^1}{E} = \sqrt{\frac{R^1}{R}},$$

$$\frac{e^1}{e} = \sqrt{\frac{R^1}{R}}.$$

General Data.—The three elements of electrical transmission of power are: (1st) The generators which are placed at the power station and which are driven by the water-wheel or steam-engine or other prime mover; (2d) the copper conductors which are placed on poles like telegraph wires, and which conduct the electric current from the generators to (3d) the motors, which deliver the electrical energy to all kinds of machinery. The motors are either belted or geared to these machines. Ordinarily electric manufacturers allow for motors up to 20 horse-power, 1,000 watts per mechanical horse-power, indicating 75 per cent. efficiency of the motor; from 20 to 50 horse-power, 900 watts per mechanical horse-power, indicating 83 per cent. efficiency of the motor; over 50 horse-power, 830 watts per mechanical horse-power, indicating 90 per cent. efficiency of the motor. A similar rule will hold good for generators. Up to 20 horse-power the output in electrical horse-power will be about 75 per cent. of the mechanical horse-power applied to the pulley. From 21 to 50 horse-power the output in electrical horse-power will be about 83 per cent. of the mechanical horse-power applied to the pulley. Over 50 horse-power the output in electrical horse-power will be about 90 per cent. of the mechanical horse-power applied to the pulley. 746 watts (one watt = ampere × volt) equal 1 electrical horse-power.

By placing the generator and motor near each other, assuming no loss in the connecting wires, we get—

One hundred per cent. mechanical energy delivered at generator pulley...	100
Loss by conversion in dynamo, 10 per cent..	10
	90
Loss by reconversion in motor, 10 per cent. of 90........................	9
	81

This shows that out of 100 mechanical horse-power applied to the generator pulley, 81 mechanical horse-power should be recovered at the motor shaft if loss in the conductors could be avoided. This efficiency of a couple of electric machines connected as generator and motor, with practically no loss in the connecting conductors, is often called the "couple efficiency."

In practice the generator and motor are so far apart that there is loss of electrical energy in overcoming the resistance of the conductors. This loss depends upon three factors, viz.: distance between generators and motors, electric pressure at generators, and size of copper conductors. For a given case the first factor, distance, is constant; pressure and size of conductors are variable and may be determined at will; therefore, the loss in the conductors may be any percentage desired. It should be stated that only "complete metallic circuits" are here considered, or, in other words, it is assumed that the generator is connected to the motor by means of two conductors. "Earth returns," which are mainly used in electric railway work, are not considered.

If a "couple efficiency" of 81 per cent. and a loss of say 10 per cent. in the conductors is assumed, there will be:

Couple efficiency..	81.0
Loss in the wire, 10 per cent. of 81	8.1
	72.9

Or the commercial efficiency of the transmission system from generator pulley to motor shaft would be 72.9, or almost 73 per cent.

Table I. (Badt's *Transmission Handbook*) shows the relations of the different factors of electrical transmission to each other, assuming an efficiency of generators and motors of 90 per cent. (or a couple efficiency of 81 per cent.), and losses in the conductors varying from 0 per cent. to 50 per cent.

Efficiency in Electric Power Transmission.

TABLE I.

1	2	3	4	5	6
Mech. H. P. required at motor shaft. N.	El. H. P. to be transmitted to motor.	Per cent. loss in conductor.	El. H. P. required in generator.	Mech. H. P. to be delivered at generator pulley.	Efficiency of whole system in per cent. *l.*
1·00	1·1111	0·0	1·1111	1·2346	81·00
1·00	1·1111	1·0	1·1223	1·2470	80·19
1·00	1·1111	2·0	1·1337	1·2597	79·38
1·00	1·1111	3·0	1·1454	1·2727	78·57
1·00	1·1111	4·0	1·1574	1·2860	77·76
1·00	1·1111	5·0	1·1696	1·2995	76·95
1·00	1·1111	6·0	1·1721	1·3134	76·14
1·00	1·1111	7·0	1·1947	1·3275	75·33
1·00	1·1111	8·0	1·2077	1·3419	74·52
1·00	1·1111	9·0	1·2210	1·3567	73·71
1·00	1·1111	10·0	1·2345	1·3717	72·90
1·00	1·1111	12·5	1·2698	1·4109	70·88
1·00	1·1111	15·0	1·3072	1·4524	68·85
1·00	1·1111	17·5	1·3468	1·4964	66·83
1·00	1·1111	20·0	1·3888	1·5447	64·80
1·00	1·1111	22·5	1·4336	1·5929	62·78
1·00	1·1111	25·0	1·4815	1·6461	60·75
1·00	1·1111	27·5	1·5325	1·7028	58·73
1·00	1·1111	30·0	1·5873	1·7636	56·70
1·00	1·1111	32·5	1·6464	1·8293	54·68
1·00	1·1111	35·0	1·7094	1·8993	52·65
1·00	1·1111	37·5	1·7778	1·9753	50·63
1·00	1·1111	38·3	1·8000	2·0000	50·00
1·00	1·1111	40·0	1·8518	2·0576	48·60
1·00	1·1111	42·5	1·9323	2·1470	46·58
1·00	1·1111	45·0	2·0201	2·2446	44·55
1·00	1·1111	47·5	2·1164	2·3515	42·53
1·00	1·1111	50·0	2·2222	2·4622	40·50

Rules for the Inter-relation of Electromotive Force, Current, Distance, Cross-section and Weight of Copper Conductor.—Frank J. Sprague, in a lecture on the "Transmission of Power by Electricity," delivered before the Franklin Institute, November 12, 1888, lays down the following important rules on the above relations :

With any amount of energy transmitted, the electromotive force and the current will vary inversely.

With any given work done, loss on the line, electromotive force at the terminals of the motor and distribution, the weight of the copper will vary as the square of the distance, its cross-section, of course, varying directly as the distance.

With the same conditions, the weight will vary inversely as the square of the electromotive force used at the motor.

With the same cross-section of conductor, the distance over which a given amount of power can be transmitted will vary as the square of the electromotive force.

If the weight of the copper is fixed, with any given amount of power transmitted and given loss in distribution, the distance over which the power can be transmitted will vary directly as the electromotive force.

With any given work done, given loss on the line and electromotive force of motor, the number of circular mils of the conductors will vary directly as the distance. Hence, with given conditions, if we double the distance we must also double the cross-section, or if we treble the distance we must treble the cross-section. The weight of a foot of the conductor of course increases also in direct proportion to its cross-section. If we therefore double both cross-section and distance, the total weight of the conductor will be increased four-fold, or if we treble both cross section and distance, the total weight of the conductor will be increased nine-fold. This shows that, with the conditions given, the weight of the copper will vary as the square of the distance.

The weight and cost of the conductor increase in direct proportion to the current. In order to get the cost of the conductor very low, it is therefore necessary to reduce the current strength to a permissible minimum. As a definite amount of electrical energy depends, however, on the product of current and electromotive force, the electromotive force must be increased in the same ratio as the current is reduced, which shows that for least cost of conductor the electromotive force of the motor must be made as high as permissible.

Conditions of Plant for Least Operating Expenses.—A certain percentage of electrical energy must be lost in the conductors; this loss, of course, involves continuous operating expense, as the prime mover (steam, water, etc.) and the electric generator must produce an additional amount of energy which is lost in the conductors. It is a loss in a commercial sense only, as this so-called "lost" energy reappears as heat in the conductor.

This loss can be decreased and power economized by using conductors of greater cross-section, which, of course, would involve a greater outlay for copper. On the other hand, to reduce the first cost, we should employ conductors of the least possible cross-section. Hence, *for*

any given case, the cheapest in the long run will be a certain size of conductor for which the interest on its first cost plus annual cost of energy wasted in the conductor, becomes a minimum.

Sir William Thomson's law states that, *The most economical area of conductor will be that for which the annual interest on capital outlay equals the annual cost of energy wasted.*

We may write this in the form of an equation: Annual cost of energy wasted = Interest on capital outlay for conductor.

The cost of one electrical horse-power hour at the terminals of the generator, including interest and depreciation on the building, motive power, and electric generator, multiplied by the number of horse-power hours per year wasted in the conductor, must be considered "cost of energy." The interest on capital outlay for conductor plus allowance for repairs and depreciation, taken for the year, gives the other side of the equation. Both sides of the equation added together, give the annual cost of transmitting the electrical energy.

Gisbert Kapp (*Electric Transmission of Power*) remarks very pertinently in this connection: "It should be remembered that this law, in the form here given, only applies to cases where the capital outlay is strictly proportional to the weight of metal contained in the conductor. In practice this is, however, seldom correct. If we have an underground cable, the cost of digging the trench and filling in again will be the same, whether the cross-sectional area of the cable be one-tenth of a square inch or one square inch; and other items, such as insulating material, are, if not quite independent of the area, at least dependent in a lesser degree than assumed in the formula. In an overhead line we may vary the thickness of the wire within fairly wide limits without having to alter the number of supports, and thus there is here also a certain portion of the capital outlay which does not depend on the area of the conductor. *Hence we should state more correctly that the most economical area of conductor is that for which the annual cost of energy wasted is equal to the annual interest on that portion of the capital outlay which can be considered to be proportional to the weight of metal used.*

"Prof. George Forbes, in his Cantor lectures on 'The Distribution of Electricity,' delivered at the Society of Arts, in 1885, called that portion of the capital outlay which is proportional to the weight of metal used, '*The Cost of Laying One Additional Ton of Copper*,' and he showed that for a given rate of interest inclusive of depreciation, and a given cost of copper, *the most economical section of the conductor is independent of the electromotive force and of the distance, and is proportional to the current.* Having in a given system of electric transmission settled what current is to be used, we can, by the aid of Sir William Thomson's law, proceed to determine the most economical size of conductor. To do this we must know the annual cost of an electrical horse-power inclusive of interest and depreciation on the building, prime mover, and dynamo; we must know what is the cost of laying one additional ton of copper, and we must settle in our mind what interest and depreciation shall be charged to the line. These points will serve to determine the constants of our formulæ, and then the calculation can easily be made."

In order to facilitate these computations, Professor Forbes published some tables. Tables II. and III., calculated by Prof. H. S. Carhart on the basis of dollars instead of pounds sterling, are here given. These tables have been calculated in such a way that when the investigator has decided upon the proper allowance to be made for cost of laying one additional ton of copper under the conditions of his particular plant, the percentage of allowance for interest, etc., he can then determine at once the proper size of conductors to employ. Thus, in Table II. he follows the columns headed with the assigned cost of conductors until he reaches the line corresponding to percentage allowed for interest, etc., and there finds a number. With this number he turns to Table III., and starting at the left, on the line marked with the number expressing the cost of one electrical horse-power per annum, he follows along to the right till he comes to the number nearest the one taken from Table II. The number standing at the head of the column in which he finds this exact or nearest approximate number is the sectional area of the conductor, in square inches or circular mils required to carry 100 amperes with maximum economy under the conditions assumed.

TABLE II.

Cost of Laying One Additional Ton of Copper. (Carhart.)

Annual allowance for interest and depreciation in %.	$300	$325	$350	$375	$400	$425	$450	$475	$500	$550	$600	$650	$700	$750	$800	$900	$1,000	$1,100	$1,200	$1,400	$1,600	$1,800	$2,000
5	030	033	035	038	040	043	045	048	050	055	060	065	070	075	080	090	100	110	120	140	160	180	200
6	036	039	042	045	048	051	054	057	060	066	072	078	084	090	096	108	120	132	144	168	192	216	240
7	042	046	049	053	056	060	063	067	070	077	084	091	098	105	112	126	140	154	168	196	224	252	280
8	048	052	056	060	064	068	072	076	080	088	096	104	112	120	128	144	160	176	192	224	256	288	320
9	054	059	063	068	072	077	081	086	090	099	108	117	126	135	144	162	180	198	216	252	288	324	360
10	060	065	070	075	080	085	090	095	100	110	120	130	140	150	160	180	200	220	240	280	320	360	400
12	072	078	084	090	096	102	108	114	120	132	144	156	168	180	192	216	240	264	288	336	384	432	480
14	084	091	098	105	112	119	126	133	140	154	168	182	196	210	224	252	280	308	336	392	448	504	560
16	096	104	112	120	128	136	144	152	160	176	192	208	224	240	256	288	320	352	384	448	512	576	640
18	108	117	126	135	144	153	162	171	180	198	216	234	252	270	288	324	360	396	432	504	576	648	720
20	120	130	140	150	160	170	180	190	200	220	240	260	280	300	320	360	400	440	480	560	640	720	800
25	150	163	175	188	200	213	225	238	250	275	300	325	350	375	400	450	500	550	600	700	800	900	1000

TABLE III.

Sectional Area for 100 *Amperes in Square Inches and Circular Mils.* (*Carhart.*)

	Circular Mils.	127,320	140,052	152,784	165,516	178,248	190,980	203,712	216,444	229,176	241,908	254,640	267,372	280,104	292,836	305,568	318,300	331,032	343,764	356,496	369,228	381,960	394,692	407,424	420,156	432,888	445,620
	Sq. ins.	·10	·11	·12	·13	·14	·15	·16	·17	·18	·19	·20	·21	·22	·23	·24	·25	·26	·27	·28	·29	·30	·31	·32	·33	·34	·35
Annual cost of one electrical horse-power at generator terminals. (Inclusive of interest and depreciation on buildings, motive power, and generator.)	$25	291	240	202	172	148	129	114	101	090	081	073	066	060	055	051	047	043	040	037	035	032	...	...	...	...	...
	30	349	289	242	207	178	155	136	121	108	097	087	079	072	066	061	056	052	048	045	042	039	036	...	...	...	...
	35	407	337	283	241	208	181	159	141	126	113	102	092	084	077	071	065	060	056	052	048	045	042	040	...	...	...
	40	465	385	323	275	238	207	182	161	144	129	116	105	096	088	081	074	069	064	059	055	052	048	045	043	...	...
	45	524	433	364	310	267	233	204	181	162	145	131	118	108	099	091	084	077	072	067	062	058	054	051	048	045	...
	50	582	481	404	344	297	259	227	201	180	161	146	132	120	110	101	093	086	080	074	069	065	061	057	053	050	048
	55	640	529	445	379	327	285	250	221	198	177	160	145	132	121	111	103	095	088	082	076	071	067	063	059	055	052
	60	698	577	485	413	356	310	273	241	216	193	175	158	144	132	121	112	103	096	089	083	076	073	068	064	060	057
	65	757	625	526	448	386	336	295	261	234	209	190	171	156	143	131	121	112	104	097	090	084	079	074	069	065	062
	70	815	673	566	482	416	362	318	281	252	225	204	185	168	154	141	131	120	112	104	097	091	085	080	075	070	067
	75	873	721	606	517	445	388	341	302	270	241	219	198	180	165	152	140	129	120	111	104	097	091	085	080	076	071
	80	931	769	647	551	475	414	364	322	287	257	233	211	192	176	162	149	138	128	119	111	103	097	091	086	081	076
	85	989	817	687	585	505	440	386	342	305	274	248	224	204	187	172	158	146	136	126	118	110	103	097	091	086	081
	90	1047	865	727	620	534	466	409	362	323	290	262	237	216	198	182	167	155	144	134	125	116	109	102	096	091	086
	95	....	914	768	654	564	491	432	383	341	306	277	251	228	209	192	177	164	152	141	131	123	115	108	102	096	090
	100	....	...	808	689	594	517	455	403	359	322	291	264	240	220	202	186	172	160	148	138	129	121	114	107	101	095
	105	....	...	...	723	624	543	477	423	377	339	306	277	252	231	212	195	181	168	156	145	136	127	119	112	106	100
	110	....	...	...	...	653	569	500	443	395	355	320	290	264	242	222	204	189	176	163	152	142	133	125	118	111	105
	115	....	...	...	...	...	595	523	463	413	371	335	304	276	253	232	214	198	184	171	159	149	139	131	123	116	109
	120	....	...	...	...	...	...	546	483	431	387	349	317	288	264	242	223	207	192	178	166	155	145	136	128	121	114
	125	....	...	...	...	...	...	...	503	449	403	364	330	301	275	253	233	215	200	186	173	162	151	142	134	126	119
	130	....	...	...	...	...	...	...	...	467	419	378	343	313	286	263	242	224	208	193	180	168	157	148	139	131	124

The following table and formulæ by Kapp (Cantor Lecture, *Journal Soc. of Arts*, July 3, 10, and 17, 1891) contains all the functions entering into any system of electric transmission:

Most Economical Current for Electric Power Transmission.

D, Distance in miles.
a, Section of conductor in square inches.
E, Terminal volts at generator.
e, Terminal volts at motor.
HP_g Brake horse-power required to drive generator.
HP_m, Brake horse-power obtained from motor.
c, Current in amperes.
Efficiency of generator, 90 per cent.; efficiency of motor, 90 per cent.
g, Cost in £ per electrical horse-power output of generator.
m, Cost in £ per brake horse-power output of motor, including regulating gear.
$G = \cdot 9gHP_g$, Cost in £ of generator.
$M = mHP_m$, Cost in £ of motor and regulating gear.
$t = 18{\cdot}2\ D_a$, Weight in tons of copper in line.
K, Cost in £ per ton of copper, including labor in erection.
s, Cost in £ of supports of line per mile run.
p, Cost in £ of one annual brake horse-power absorbed by generator.
q, Percentage for interest and depreciation on the whole plant.

$$\text{Capital outlay} = g\frac{Fc}{746} + mHP_m + Ds + \frac{1{\cdot}6\,KD^2c^2}{Ec - 830HP_m} = A.$$

$$\text{Annual cost per brake horse-power delivered} = q\,\frac{A}{HP_m} + p\,\frac{HP_g}{HP_m}.$$

$$\text{Put } B = \frac{Ep}{670} + g\,\frac{Eg}{746}.$$

$$\gamma = \frac{830}{E} HP_m,$$

the current which would be required if the line had no resistance, and

$$\beta = \gamma^2 \frac{EB}{1{\cdot}6qKD^2 + EB}.$$

Then the most economical current at the given voltage, E, is:

$$c = \gamma \left\{ 1 + \sqrt{1 - \frac{\beta}{\gamma^2}} \right\}$$

$$c = \gamma \left\{ 1 + \sqrt{\frac{1\ 6qKD^2}{1{\cdot}6qKD^2 + BE}} \right\}$$

For very long distances the term under the square root approaches unity, and the most economical current the value 2γ; from which it follows that under no circumstances will it be economical to lose more than half the total power in the line.

Sprague has developed some very interesting formulæ, from which he deduces the following laws:

With fixed conditions of cost and efficiency of apparatus, the number of volts fall to get the minimum cost of the plant is a function of distance alone, and is independent of the electromotive force used at the motor.

With any fixed couple and commercial efficiency, the cost of the wire bears a definite and fixed ratio to the cost of the generating plant.

The cost of the wire varies directly with the cost of the generating plant.

If we do not limit ourselves in the electromotive force used, the cost per horse-power delivered exclusive of line erection is, for least cost and for a given commercial efficiency, absolutely independent of the distance.

By the aid of these laws and Sprague's formulæ, and assuming—

$K =$	Cost in cents of *bare* copper wire per lb. delivered at the poles	$= 25$
$a =$	Commercial efficiency of motor	$= \cdot 90$
$b =$	Commercial efficiency of generator	$= \cdot 90$
$G =$	Cost in dollars of generator set up, per electric horse-power delivered at its terminals	$= 45$
$P =$	Cost in dollars of power (water) set up per mechanical horse-power delivered at generator pulleys	$= 25$

—the accompanying diagram, Fig. 1, has been constructed, which shows the commercial

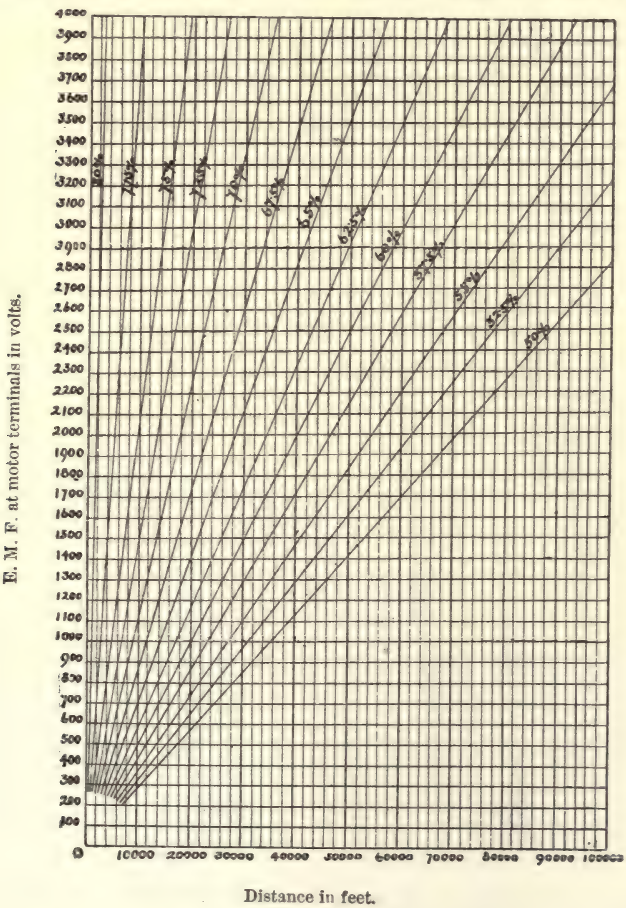


FIG. 1.

efficiency at various distances and voltages for a minimum total initial cost of a transmission plant.

As with fixed conditions of cost and efficiency of apparatus, the number of volts to get the minimum cost of plant is a function of the distance alone, and is independent of the

electromotive force used at the motor, Table IV. can be calculated. The values for K, a, b, G, and P, are assumed as before.

TABLE IV.

Distance in feet plus 5 per cent. sag.	Volts lost in conductor for minimum cost of plant.	Distance in feet plus 5 per cent. sag.	Volts lost in conductor, for minimum cost of plant.
1,000	17·5	18,000	315
2,000	35	20,000	350
3,000	52·5	25,000	437·5
4,000	70	30,000	525
5,000	87·5	35,000	612·5
6,000	105	40,000	700
7,000	122·5	45,000	787·5
8,000	140	50,000	875
9,000	157·5	60,000	1,050
10,000	175	70,000	1,225
12,000	210	80,000	1,400
14,000	245	90,000	1,575
16,000	280	100,000	1,750

Badt (*Electric Transmission Hand-Book*) expresses the principles governing the minimum cost of a transmission plant, in the following rule :

For minimum initial cost of plant, and assuming certain prices per horse-power of motors, generators, and power plant (all erected and ready for operation), and assuming a certain price per pound of copper (delivered at the poles), the total cost of the plant, excluding line construction, is a constant for a certain efficiency of the electric system, no matter what the electromotive force of the motor and the distance may be.

At a given efficiency of the electric system, the electromotive force of the motor and distance will increase and decrease in the same ratio.

This rule is embodied in Table V., from which it will be seen, for instance, that the cost of plant per horse-power delivered by motor at 1,000 volts and 25,000 ft. distance, and at an efficiency of 56·4 per cent., is $205.82. It will also be seen that the cost is the same at 4,000 volts, 100,000 ft. distance, and the same efficiency of 56·4 per cent. While the cost and efficiency in both cases are the same, with an electromotive force four times greater we can reach four times the distance.

TABLE V.

Electric Power Transmission Data for Minimum Initial Cost of Plant. (*Badt.*)

(Per mechanical horse-power delivered by motor.)

BASIS OF CALCULATIONS.			MOTOR. (90 per ct. efficiency.)		CONDUCTOR. (Bare copper.)				GENERATOR. (90 per ct. efficiency.)			COST IN DOLLARS of electric plant, excluding line erection.					
Distance in feet.	E. M. F. at motor terminals.	Efficiency of electric system.	El. H. P. at terminals.	Amperes.	Volts lost in conductor.	Per ct. lost in conductor	Cross-section in C. M.	Weight in lbs.	Output in El H. P.	Mech. H. P. required to drive.	E. M. F. at terminals.	Motor.	Conductor.	Generator.	Total of electric plant.	Power plant (water)	GRAND TOTAL. (Excluding line erection.)
D	E	l	$\frac{1}{\cdot 90}$	$\frac{746}{E}$	V	Per ct.	C.M.	Wt. lbs.	$\frac{\cdot 90}{l}$	$\frac{1}{l}$	E + V	50	K x lbs.	$\frac{\cdot 9 \times G}{l}$		$\frac{P}{l}$	
5,000	500	68·9	1·11	1·492	87·5	14·9	2032	63·5	1·29	1·45	587·5	50	15·87	58·54	124·41	36·28	160·69
10,000	500	60·0	1·11	1·492	175·0	25·9	2032	127·0	1·50	1·67	675	50	31·75	67·50	149·25	41·67	190·92
16,000	500	51·9	1·11	1·492	280·0	35·9	2032	203·2	1·74	1·93	780	50	50·80	78·04	178·84	48·17	227·01
5,000	1,000	74·4	1·11	0·746	87·5	8·1	1016	31.75	1·21	1·34	1087·5	50	7·94	54·43	112·37	33·60	145·97
10,000	1,000	68·9	1·11	0·746	175·0	14·9	1016	68·5	1·31	1·45	1175	50	15·88	58·78	124·66	36·28	160·94
16,000	1,000	63·3	1·11	0·746	280·0	21·9	1016	101·6	1·42	1·58	1280	50	25·40	63·98	139·38	39·49	178·87
25,000	1,000	56·4	1·11	0·746	437·5	30·4	1016	158·7	1·59	1·77	1437·5	50	39·68	71·81	161·49	44·33	205·82
35,000	1,000	50·2	1·11	0·746	612·5	38·0	1016	222·2	1·79	1·99	1612·5	50	55·54	80·68	185·92	49·80	235·72
35,000	4,000	70·2	1·11	0·1865	612·5	13·3	254	55·6	1·28	1·42	4612·5	50	13·90	57·69	121·59	35·61	157·20
70,000	4,000	62	1·11	0·1865	1125	23·4	254	111·1	1·45	1·61	5225	50	27·78	65·32	143·10	40·32	183·42
100,000	4,000	56·4	1·11	0·1865	1750	30·4	254	158·7	1·59	1·77	5750	50	39·68	71·81	161·49	44·33	205·82

REMARKS.

G = Cost of generator delivered and erected, including electrical instruments, per electric horse-power, delivered at generator terminals = $45.00.

P = Cost of power plant (water) erected, per mechanical horse-power, delivered at generator pulleys = $25.00.

M = Cost in cents of *bare* copper wire per lb., delivered at the poles = 25 cents.

The annexed comparative table shows the commercial efficiency of four different systems of transmission. See Table VI.

TABLE VI.

Commercial Efficiency.

Distance of transmission.	Electric.	Hydraulic.	Pneumatic.	Wire Rope.
100 m.	·69	·50	·55	·96
500 m.	·68	·50	·55	·93
1,000 m.	·66	·50	·55	·90
5,000 m.	·60	·40	·50	·60
10,000 m.	·51	·35	·50	·36
20,000 m.	·32	·20	·40	·13

It will be seen that for distances less than 5 kilometres (about three miles) transmission by wire rope is more economical than that by any other system. For distances greater than 5 kilometres the electric transmission is most economical. As regards capital outlay, the wire-rope system is also for short distances more advantageous than electric transmission, the limit being at about 3 kilometres (a little under two miles). Beyond that the electrical system is the cheapest, as will be seen from the annexed Table VII.

TABLE VII.

Capital Outlay in Pounds Sterling reduced to one Horse-power. (*Kapp.*)

Maximum horse-power transmitted	System of transmission.	Over a distance of					
		100 m.	500 m.	1,000 m.	5 000 m.	10,000 m.	20,000 m.
5	Electric	75	78	81	108	142	210
	Hydraulic	41	66	97	358	610	1,280
	Pneumatic	73	96	210	600	1,090	2,060
	Wire Rope	6.5	31	61	305	760	1,220
10	Electric	52	54	56	77	103	154
	Hydraulic	30	45	65	220	416	806
	Pneumatic	60	72	88	213	369	680
	Wire Rope	5.1	23	47	231	460	925
50	Electric	40	41	42	55	69	100
	Hydraulic	16	21	30	91	170	325
	Pneumatic	31	36	42	88	147	265
	Wire Rope	1.8	72	14	69	136	272
100	Electric	32	33	35	45	59	87
	Hydraulic	14	20	28	88	164	310
	Pneumatic	26	30	34	67	109	192
	Wire Rope	1.1	43	84	41	81	162

The table shows that for short distances the cost of electric transmission is very considerable as compared to that of the other systems. The reason for this is that the price of dynamos and motors have been rather overestimated in the above table. For long distances this is not so noticeable, as the conductor forms the more important item, and especially since an electric wire is cheaper than an equivalent hydraulic or pneumatic tube. If we compare the conductors only, we find that for the transmission of 10 horse-power, a copper wire of 127 mils diameter [No. $10\frac{1}{2}$ B. W. G.] is equivalent to a water-pipe of $3\frac{7}{8}$ in. diameter, or to an air-pipe of $3\frac{1}{8}$ in. diameter, or to a wire rope of $\frac{5}{16}$ in. diameter. The proportion between the cost of these conductors calculated for equal distances is as 1·4 : 34·8 : 27·8 : 1. The conductor with hydraulic transmission costs, therefore, twenty-five times as much, and with pneumatic transmission it costs nearly twenty times as much as with electric transmission. These figures prove that as far as capital outlay is concerned, the electric system has the greatest advantage where the conductor is long, that is, where the energy has to be transmitted over a long distance. It would, however, not be correct to compare the four systems on this basis alone. The comparison must be made on the question of capital outlay combined with efficiency; in other words, the figure of merit for each system is the price which has to be paid for 1 horse-power-hour at the receiving station. The smaller this price, the better the system. A glance at the annexed table (see Table VIII.) will show that the cost of 1 horse-power-hour increases in all systems with the distance, but with electric transmission the increase is not so rapid as with the other systems. The table also shows that up to a distance of 1,000 meters [five-eighths of a mile], wire-rope transmission is better than electric transmission, but above that limit the electrical system is better. Hydraulic and pneumatic transmission are in some few cases better than electric transmission, but then the wire rope is again better than either, so that there does not seem to be a field for the application of the hydraulic or pneumatic system, except in cases where the other two systems are for some local reason inadmissible, or where the water and air may be of further use after the power has been obtained from them. This, for instance, is the case with the pneumatic transmission employed in the building of tunnels. Here it is an absolute necessity to force air to the end of the workings for ventilating purposes, and pneumatic transmission is

adopted in preference to any other system which would require some special ventilating plant being erected.

TABLE VIII.

Price in Pence of One Horse-power Hour obtained at the Receiving Station. (*Kapp.*)

Maximum horse-power transmitted.	System of transmission.	Steam-power transmitted over a distance of						Water-power transmitted over a distance of						Cost of steam-power produced at receiving station.
		100 m.	500 m.	1,000 m.	5,000 m.	10,300 m.	20,000 m.	100 m.	500 m.	1,000 m.	5,000 m.	10,000 m.	20,000 m.	
5....	Electric	2·25	2·33	2·41	2·87	3·29	5·20	·35	·36	·37	·44	·52	·84	..3·80
	Hydraulic...	2·50	2·84	3·15	6·52	10·50	19·00	·29	·38	·48	1·38	2·50	4·79	
	Pneumatic..	2·70	2·96	3·30	5·25	9·53	16·72	·40	·47	·58	1·27	2·40	4·45	
	Wire Rope..	1·13	1·45	1·88	5·45	10·40	22·70	·11	·19	·30	1·25	2·50	4·86	
10...	Electric.....	1·98	2·07	2·14	2·53	3·10	4·85	·27	·28	·29	·36	·47	·71	..2·63
	Hydraulic...	2·38	2·55	2·79	5·08	7·70	14·30	·25	·30	·37	·95	1·54	3·17	
	Pneumatic..	2·54	2·69	2·87	4·48	6·25	10·40	·35	·38	·44	·88	1·42	3·97	
	Wire Rope..	1·12	1·38	1·70	4·50	8·50	19·10	·09	·17	·25	·96	1·91	4·00	
50...	Electric.....	1·87	1·94	1·99	2·28	2·74	4·25	·23	·24	·26	·29	·31	·55	..1·02
	Hydraulic...	1·63	1·70	1·80	2·90	4·21	7·80	·15	·18	·22	·46	·76	1·43	
	Pneumatic..	2·02	2·11	2·18	2·87	3·54	5·30	·22	·24	·28	·44	·65	1·08	
	Wire Rope..	1·08	1·18	1·30	2·54	4·51	11·10	·09	·11	·13	·38	·72	1·61	
100...	Electric.....	1·79	1·85	1·91	2·18	2·63	4·08	·20	·22	·23	·26	·32	·50	..1·02
	Hydraulic...	1·62	1·70	1·78	2·87	4·15	6·84	·16	·17	·19	·43	·72	1·14	
	Pneumatic..	2·00	2·04	2·09	2·63	3·10	4·50	·22	·23	·24	·36	·48	·33	
	Wire Rope..	1·07	1·14	1·22	2·21	3·83	9·73	·08	·10	·11	·28	·48	1·19	

Long-distance Transmissions.—The first real long-distance electric power transmission was carried out by Marcel Deprez at the Munich Exposition of 1882, with two Gramme machines as motor and generator. These were placed respectively at Munich and at Miesbach, a distance apart of 57 kilometres (37 miles). They were connected by an ordinary iron telegraph wire, 4½ mm. in diameter, and constituted a complete metallic circuit of 114 kilometres (74 miles) in length. The resistance of the line measured 950·2 ohms; that of the generating machine at Miesbach, 453·4 ohms; and that of the motor at Munich, 453·4.

Speed of generator at Miesbach	1,611 revolutions.
Intensity of current at Miesbach	0·519 ampere.
Speed of motor at Munich	752 revolutions.
Difference of potential at terminals of motor	850 volts.
Work measured by brake at motor.......................	0·25 H. P.

From these data the following values were calculated :

Difference of potential at terminals of generator........	1,343 volts.
Total electrical energy at Miesbach.....................	1·13 H. P.
Total electrical energy at Munich	0·433 H. P.
Electrical efficiency	38·9 per cent.

It will be understood here that this efficiency is not the *absolute* or commercial efficiency, but the *electrical* alone.

These were followed by other experiments, but probably the most important of M. Deprez's transmissions was that undertaken by him in 1885 between Paris and Creil, a distance of 34 miles. The line consisted of a lead-encased insulated copper wire, 5 mm. in diameter, and its resistance was 100 ohms. The generating machine was situated at Creil. It had two rings revolving in two distinct magnetic fields, each composed of eight electro-magnets. Each armature had a resistance of 16·5 ohms. The current produced by this machine was utilized at La Chapelle, near Paris, by two receiving machines, situated at some hundreds of metres from each other. Each possessed, like the generator described, two rings ; they were each of 0·58 metre in exterior diameter and had an electric resistance of 18 ohms. In a note presented to the French Academy of Sciences, M. Deprez gave the results of experiments undertaken with these machines, and they are quoted below:

First Experiment.

	Generator.	Receiver.
Speed in revolutions per minute..................	190	248
Electromotive force, direct or inverse............	5,469 volts.	4,242 volts.
Intensity of current.............................	7·21 amp.	7·21 amp.
Work in field magnets (in horse-power)..........	9·20	3·75
Electrical work (in horse-power)	53·59	41·44
Mechanical work measured with the dynamometer or the brake (horse-power)..................	62·10	35·10

Efficiency.

Electrical .... 77 per cent.
Commercial or mechanical.................................. 47·7 per cent.

Second Experiment.

	Generator.	Receiver.
Speed per minute	170	277
Electromotive force	5,717 volts.	4,441 volts.
Intensity of current	7·20 amp.	7·20 amp.
Work in field magnets	10·30 H. P.	3·80 H. P.
Electrical work..................................	55·90 "	43·4 "
Mechanical work (measured with the dynamometer or the brake)	61 "	40 "

Efficiency.

Electrical .... 78 per cent.
Commercial or mechanical.................................. 53·4 per cent.

In October, 1887, a committee of experts carried out a series of tests on the electrical transmission plant between Kriegstetten and Solothurn, Switzerland. At Kriegstetten, there is a water-power available, representing about forty actual horse-power, and the problem was to carry as much of this power as possible to a mill in Solothurn, the distance being 5 miles. There are at Kriegstetten two generating dynamos, and at Solothurn two motors, coupled up on the three-wire system. Each dynamo weighs 3 tons 12 cwt., and has a Gramme armature 20 in. in diameter and 14 in. long, the normal speed being 700 revolutions per minute. The following tables give the results of these tests :

I. *Electrical Measurements.* II. *Resistances and Loss of Pressure.*

No.	Electromotive force.		Terminal pressure.		Current measured at		Resistance of machines.		Line resistance.	Pressure lost in line.		Temperature of air, centigrade.
	Generators.	Motors.	Generators.	Motors.	Generators.	Motors.	Generators.	Motors.		Calculated.	Measured.	
1	1231·6	988·6	1177·7	1041·2	14·20	14·17	3·741	3·716	9·228	130·9	136·5	+7·5
2	1237·0	1016·8	1186·8	1066·1	13·24	13·28	3·741	3·710	9·228	122·3	120·7	+7·5
3	1836·5	1575·4	1753·3	1656·1	11·48	11·42	7·251	7·060	9·044	103·7	97·2	+3·2
4	2129·0	1896·2	2058·0	1965·1	9·78	9·79	7·240	7·052	9·040	88·4	92·8	+3·2

III. *Determination of Energy.* IV. *Percentage of Efficiencies.*

No.	Internal electrical horse-power.		Terminal electrical horse-power.		Actual horse-power		Electrical efficiency.		Commercial efficiency.		Total efficiency of transmission.	Remarks.
	Generators.	Motors.	Generators.	Motors.	Supplied to generators.	Obtained from motors.	Generators.	Motors.	Generators.	Motors.		
1	23·76	19·03	22·72	20·02	26·15	17·85	90·7	93·7	86·8	89·1	68·3	One generator and one motor.
2	22·27	18·34	21·35	19·23	24·54	16·74	90·6	91·3	86·9	87·1	68·2	
3	28·64	24·46	27·34	25·71	30·87	23·21	92·8	94·8	88·5	90·3	75·2	Both generators and both motors.
4	28·29	25·21	27·37	26·13	30·87	23·05	91·6	91·4	88·7	88·2	74·6	

A. L. Rohrer, of the Thomson-Houston Electric Co., has applied a plan for a large power plant by which 5,000 horse-power is being transmitted a distance of twelve miles. The diagram, Fig. 2, shows the arrangement. By this arrangement, the generators are coupled mechanically in pairs as *one* unit on one shaft driven by *one* turbine, and electrically the armatures of each unit are connected in series. Each armature has a potential of 2,500 volts. This gives 5,000 volts for each unit at the generating station. The generators are separately excited, and have also series windings, which compensate for the loss in the line. At the receiving station there are the same number of units, each consisting of two similar machines, with their armatures in series, and their fields separately excited, but without series winding. Each receiving unit is coupled to the same shaft in the same manner as the generating unit. At the generating station exciters are only used for charging the fields, while at the receiving station exciters are used in connection with a small storage battery which is necessary to start the first unit. The mechanically and electrically

coupled units at the generating station are united electrically in parallel in one system, by an equalizing bar, as shown in the diagram. It seems advisable to leave the storage battery in the circuit permanently, to keep the fields of the motors fully excited, in case the speed should drop. In another instance, 250 horse-power is transmitted a distance of 10 miles with single series-wound units. Each machine is wound for a potential of 3,000 volts, and for this purpose a special commutator with 798 segments was constructed.

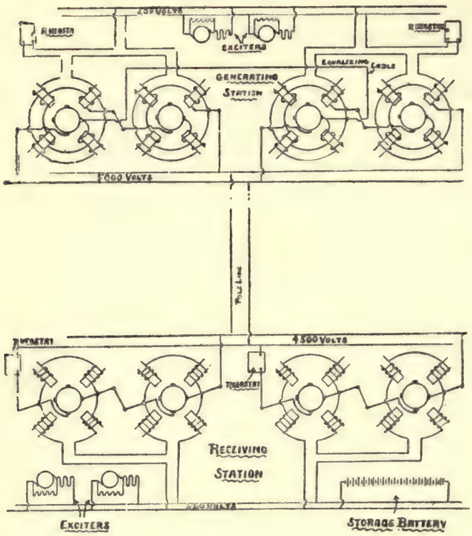


Fig. 2.

An example of a large modern transmission plant is that erected in 1890 for the Schaffhausen Spinning Mills in Switzerland. This example is not only interesting on account of its magnitude, but because it has been planted, so to say, into the very stronghold of rope transmission, namely, at the Falls of the Rhine, where the last generation of Swiss engineers carried out such admirable work in teledynamic transmission that the present generation can only copy, but cannot improve upon it.

The spinning mills are on one side, and the generating station is on the other side of the river, the distance between the two being about 750 yards. In the generating station there is room for five 350 horse-power turbines, of which four are now in place, but of these only two are as yet used in connection with the electric power transmission. The power of these turbines is sold to the spinning company at the rate of $13.75 per annual horse-power taken off the rope pulleys. The turbines are horizontal wheels, and their vertical axes are geared by bevel wheels with the rope pulleys, by which motion is conveyed through cotton ropes to the two generating dynamos. The latter are six-pole machines, each designed for an output of 330 amperes at 624 volts, and in regular work these machines are coupled parallel. The machines, and, in fact, the whole installation, with the exception of the hydraulic works, were designed by Mr. C. E. L. Brown. The generating station contains two 300 horse-power dynamos, which are over-compounded, so as to produce a constant pressure of 600 volts at the motor station, the loss in the line being with full current 24 volts. These machines have series wound drum armatures, running at 200 revolutions per minute. Their more important electrical data, as well as those referring to the motors, are given in the following table:

Schaffhausen Transmission Plant.

	Generators.	Twin Motor.	Small Motors.
Number of machines	2	1	2
Normal horse-power	300	380	60
Number of poles in magnet field	6	6	2
Revolutions per minute	300	300	350
Terminal voltage	624	600	600
Normal current, amperes	330	500	81
Diameter of armature, inches	47¼	42½	23⅝
Length of armature core, inches	20	20⅝	22½
Radial depth of armature, core inches	8	7	4¾
Section of armature conductor, square inches	103	078	0287
Number of armature conductors	316	316	540
Number of commutator segments	153	153	90
Loss in armature resistance, per cent	1·46	1·52	2·7
Induction in armature, C. G. S. measure	7,500	7,600	15,800
Shunt resistance, ohms	140	143	295
Loss in shunt excitation, per cent	1·35	1·68	......
Main turns per magnet	6	4	....
Loss in main excitation, per cent	3	2	....
Type of armature	Drum	Drum	Cylinder

A most remarkable example of electric-power transmission is that at the Chollar mine, Virginia City, Nevada. The Nevada Stamp Mill is located near the shaft of the Chollar mine, and is driven by water-power from a reservoir on the side of the mountain, which was not adequate for the full operation of the machinery.

At the 1,650-ft. level of the Chollar mine, a subterranean chamber was excavated out of

solid porphyry, for the reception of the dynamo-electric generators and water-wheels. This chamber is 50 ft. in length and 25 ft. in width and 12 ft. in height, clear of all timbers. From the tank containing the waste surface water, two wrought-iron pipes are led to the subterranean chamber, one 10 and one 8 in. in diameter. At the bottom of the shaft a Y unites these two pipes into a single one, 14 in. in diameter, out of which six 6-in. pipes run to the nozzles of the water-wheels provided to drive the large Brush dynamo-electric generators. The underground electric station is of the most interesting character. The large Brush generators are adapted to the conditions by a few mechanical changes from the standard pattern. They are mounted on a heavy cast-iron base, and are provided with an extended shaft and outer bearing. On each armature shaft and between two bearings a Pelton water-wheel is mounted and inclosed in a water-tight cover. The water-wheel is attached to the armature shaft at the place occupied by the pulley, and a coupling is provided for detaching the entire end of the shaft carrying the wheel from the other end carrying the armature. (See WATER-WHEELS.)

The head of water at this station is 1,650 ft., and the waste is run off through the Sutro tunnel. From each generator the current is led by conductors through the shaft to the surface, where six motors are driven, and the power utilized in supplementing the water-wheel at the stamp mill above. The economic value of this arrangement is shown by the following facts: The surface wheel alone requires 312 miner's inches of water to develop power sufficient to drive 40 of the 60 stamps with which the mill is equipped. Moreover, this amount of water is seldom available. Two of the electric motors, working in addition to the surface wheel, will perform the same service with but 72 miner's inches of water, thus effecting a saving of about 77 per cent. The net commercial efficiency of the plant, taking into account all elements of loss, including that in the conducting wires, is about 70 per cent. In other words, 70 per cent. of the power applied to the shafts of the generators in the underground chamber is delivered for work at the main shaft in the mill.

The most recent example of long-distance electric transmission is that carried out in connection with the Electrical Exhibition at Frankfort-on-the-Main, Germany, 1891. A water-power of 300 horse-power, situated at Lauffen on the Neckar, was carried over three wires to Frankfort, a distance of 112 miles, at a potential of over 20,000 volts. The polyphase system of Nikola Tesla was employed, the transformers and dynamos being constructed by the Oerlikon Works, Switzerland, and the motors designed by Dolivo-Dobrowolski, of the Allgemeine Elektricitäts Gesellschaft, Berlin. The report of the tests of this installation has not yet (January, 1892) been published.

[For more complete discussion and descriptions of electric-power transmissions, reference may be had to the following works, which have been freely quoted in the above: *Electric Transmission Handbook*, by F. B. Badt; *Electric Transmission of Energy*, by Gisbert Kapp, C.E.; *Kritische Vergleichung der Kraftuebertragung mit den Gebraeuchlichsten Mechanischen Uebertragungs Systemen*, by A. Beringer; *Dynamo Electric Machinery*, by Prof. S. P. Thompson; *The Electric Motor and Its Applications*, by T. C. Martin and Joseph Wetzler; *Electric Motors*, by F. J. Sprague (late Ensign U. S. N.), a paper read before U. S. Naval Institute, Annapolis, May 16, 1887; *The Transmission of Power by Electricity*, by F. J. Sprague, a lecture delivered before the Franklin Institute, November 12, 1888; *Some Applications of Electric Transmission*, by F. J. Sprague, a lecture delivered before the students of Sibley College and published in the *Scientific American Supplement*, July 20 and 27 and August 3, 1889; the papers of George W. Mansfield, Richard P. Rothwell, Francis A. Pocock, H. C. Spaulding, and others, read before the American Institute of Mining Engineers; and the paper of H. Ward Leonard, read before the Association of Mining Engineers of the Province of Quebec, April 29, 1891; and an article by the same author in *The Electrical Engineer*, September 2, 1891. Also "Cantor Lectures on the Electric Transmission of Power," by G. Kapp, *Journal Society of Arts*, July 3, 10, and 17, 1891.]

POWER, TRANSMISSION OF, HYDRAULIC, ETC. (For Electrical Transmission of Power, see POWER, TRANSMISSION OF, ELECTRIC. For Mechanical Transmission of Power, see BELTS. For Transmission by Compressed Air, see AIR COMPRESSORS. See also NIAGARA, UTILIZATION OF.)

HYDRAULIC TRANSMISSION OF POWER.—Transmission of power for lifting, etc., by water under pressure is in common use in steel works and other large manufactories, but it is not generally adopted for long distances, transmission by compressed air, by steam-pipes, or by electricity being usually preferred. It is, however, a valuable system for districts in cities where there is much lifting to be done, as in warehouses. The most extensive application of this system is that made by the London Hydraulic Power Co. Over 50 miles of hydraulic mains have been laid in London, embracing nearly the whole city, Westminster, and Southwark. The mains laid in the street are from 7 in. internal diameter to 2 in. They are chiefly of cast-iron with flanged joints and packing rings of gutta-percha. The mains are kept charged by powerful pumping engines. The reservoirs of power consist of capacious accumulators, loaded to give a pressure of 750 lbs. per sq. in., producing the same effect as if large supply-tanks were placed at 1,700 ft. above the street-level. The water used is pumped direct from the river. The hydraulic power is supplied direct to elevators, presses, and fire hydrants and other apparatus of similar character, without the use of any engine or power-producing machinery, but the hydraulic pressure can also be used for driving engines of special construction in the same way as steam or gas. Hydraulic engines worked from the company's mains are now used for all sorts of purposes, such as coffee-grinding, ventilating, working elevators and crushers, driving dynamos and general machinery. The hydraulic

power is also used for pumping water from deep wells or from the basement of a building to a tank on the roof, or for the drainage of cellars, and for supplementing the deficiency of pressure from the water-works mains.

A valuable paper on waste of power in hydraulic transmission, by Mr. R. G. Blaine, will be found in *Engineering*, May 22, 1891. Mr. Blaine deduces the formula,

$$W = \cdot 6367\, \lambda \frac{LE^3}{p^3\, d^5},$$

in which L = length of pipe in feet; d = diameter in feet; E = horse-power sent into pipe at one end, and p = equals pressure at entrance in pounds per square inch. Values of the coefficient $\cdot 6367\, \lambda$, for diameters ½ in. to 12 in. are as follows:

Diameter.	Coefficient.
½ in.	·00955
1	·00637
2	·00478
3	·00420
4	·00395
5	·00382
6	·00369
7	·00363
8	·00357
10	·00350
12	·00344

Example.—If 100 horse-power are sent into a straight pipe one mile long and 6 ins. in diameter, the entering pressure being 700 lbs. per sq. in., find the power wasted in transmission.

Here

$$W = \frac{\cdot 00369 \times 5280 \times 100^3}{700^3 \times (\cdot 5)^5} = 1 \cdot 82 \text{ horse-power.}$$

This method shows how to calculate the power wasted in friction in straight pipes of any hydraulic system. There are, however, certain other sources of loss, such as bends in the pipe, roughness of its inner surface, etc., which cannot well be taken into account, making the result less favorable in regard to the efficiency of the system. In connection with the energy wasted at bends, the reader is referred to Weisbach's *Hydraulics*, or to the article by Professor Unwin on "Hydromechanics" in the *Encyclopædia Britannica*. Mr. Blaine, in *Engineering*, June 5, 1891, has, with the above method as a basis, worked out a method of calculating the most economical diameter of pipe for a given horse-power and distance, and compared the efficiency with that of electric transmission under certain specified conditions.

The Distribution of Heat and Power by Hot Water will be found described in a paper by Mr. A. V. Abbott, Trans. Am. Inst. Mining Engrs., February, 1888. This system was tried in Boston, but not successfully. Water was delivered to the customers at a temperature of 400° F., corresponding to 250 lbs. absolute pressure to the square inch. It is not improbable that with improvements in certain details and situations, this system may prove of value and importance.

Transmission of Power through a Vacuum.—This system, as practiced in Paris by MM. Petit and Boudenott, consists in maintaining, by means of exhausting engines working at a central station, a reduced pressure in the mains to the amount of as nearly as possible two-thirds of a perfect vacuum. Service pipes from the mains pass into the premises of the users, and are connected with the motors; and work is thus performed by the difference in pressure between the atmosphere and the vacuum in the mains. The exhausting engines do not exhaust direct from the mains, but from a reservoir serving to some extent as a regulator, from which the mains are laid either under the streets or in the subways; and the motors are started or stopped by simply opening or closing a valve on the service pipe. There are three exhausting engines of about 90 horse-power each; one of them is independent, while the other two can be coupled together. The steam cylinder is 13¾ in. diameter and 42 in. stroke, and works with a boiler pressure of 85 lbs. per sq. in. The exhausting cylinder of 41 in. diameter is in the same line with the steam cylinder, both pistons being on the same rod. Pressure regulators, indicators, and counters, record continuously the vacuum in the mains and the revolutions made by the engines, whereby a check is obtained upon the amount of power supplied. The motors are made in three sizes, of ½ horse-power, 1 horse-power, and 1½ horse-power; the last seems to be the maximum that can be worked with advantage, and where more power is required it is obtained by coupling two motors together. The present length of the exhaust mains from the central station is about a thousand yards.

Press: see Book-binding Machines, Glass-making, Mills, Silver, and Wheel-making Machines.

PRESSES, PRINTING. *The Hoe Rotary Art Press.*—With the growth of magazines and the advance of their artistic character has come the demand for machinery capable of producing the highest class of illustrated work at great speed, and it is to meet this demand that the Hoe rotary art press, Fig. 1, has recently been constructed for the illustrated pages

of *The Century Magazine.* This is the first machine ever made on the rotary principle and designed for the finest quality of illustrations, taking the place of the Hoe stop-cylinder presses, on which this grade of work has heretofore been done. The plates used are electrotypes of standard thickness, bent to the proper curve by a little machine furnished for the purpose. Each electrotype plate contains a page of the magazine and is locked upon curved blocks, which are securely fastened upon the circumference of one cylinder. Sixteen form rollers, supplied with ink from two fountains, give the required amount of ink to the plates. The plates are inked with delicacy and fullness of color. The sheets of paper, each of the size of 32 magazine pages, are fed to the machine in the usual way, by hand, but by four feeders. The sheets are drawn between the impression cylinder and the plate cylinder, receiving the impression.

After passing around the cylinders they are carried to the two fly deliveries, one above the other, each of which throws out two sheets of 16 pages each. The sheets come out in four separate lots, those which each man feeds to the press being delivered in one compartment. The individual work of the feeder is thus accurately known.

It was a general belief not long since that the finest quality of illustrated work could be done only on hand presses, but the progress in the development of cylinder presses has made possible a high order of illustration at a much greater speed. The rotary art press has the

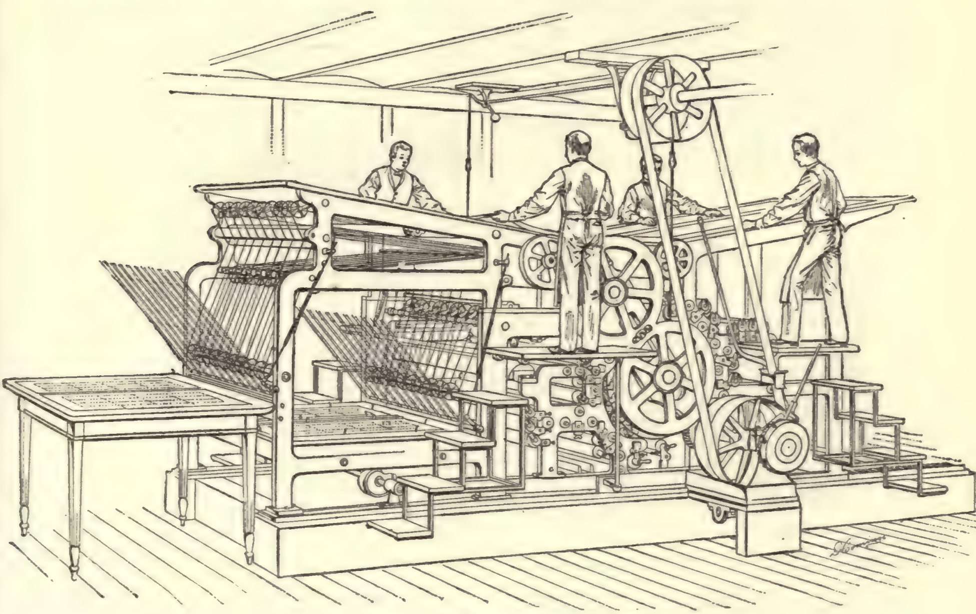


FIG. 1.—The Hoe rotary art press.

capacity of four stop-cylinder presses, and is claimed to do even a higher quality of work than the stop-cylinder presses.

Cottrell's Improved Two-color Press is especially designed for bag printing in colors, and is applicable to many other styles and qualities of fine printing. The press is a two-roller drum-cylinder machine, to which is attached a supplementary cylinder of half the diameter of the drum. It is constructed to admit of curved stereotype or electrotype plates, and is furnished with fountain distributors, etc. There is also a patent device for controlling the momentum of the cylinder. In all cylinder presses (except the stop-cylinder) there is more or less backlash within the gearing, arising from the clearance of the teeth, and from the tendency of the cylinder to maintain its velocity while the bed is slowed down to pass the center. To obviate this, a patent device for controlling the momentum of the cylinder is used. It checks the momentum of the cylinder at the right time, keeps the gears up to the working sides of the teeth, and harmonizes the regular velocity of the cylinder to the irregular velocity of the bed, relieves the gearing of all unnatural strain, and accurate register at any speed is thus secured. It consists of a brake-shoe attached to the framework and made adjustable at the box. The brake-shoe is adjusted to engage with the friction face secured to the cylinder shaft, with sufficient friction to gradually check the momentum of the cylinder at the proper time.

The Hoe Century Press.—The illustrated pages of a magazine form but a part of the work of its publication. There remain the plain forms and advertising pages to be produced, and the quantity of these is now so great that to continue to print them on the ordinary cylinder press is no longer economical, indeed hardly practicable. To meet the new de-

mand, the *Century* press has been built. The arrangement of this press (see Fig. 2) is similar to the Hoe fast newspaper press, but the plate and impression cylinders are placed nearly on a level, and at a height that makes them easily accessible to the pressman. The distribution is effected by two large and two small ink cylinders for each fountain, with an adequate service of distributing rollers. The inking rollers are six in number, with an additional composition roller for cleaning the form. The plates used are electrotypes of the usual thickness, viz.: $\frac{2}{12}$ of an inch, containing each one page of the magazine, and mechanically bent to the requisite press cylinder. The plates are each secured upon a curved iron stereotype block, locked up by a rack and pinion in the usual manner, and these curved blocks are in turn fastened securely to the surface of the plate cylinders, the pages being placed longitudinally. The roll of paper is at the end of the press and is controlled in momentum by the usual hand brake. From it the web is drawn by tension in the usual manner through the printing cylinders, and is then cut into transverse sections, containing 8 pages on each side, or 16 on the two sides. These sections are gathered by a collecting cylinder in pairs, one above the other; then receive a transverse fold between the two pages, and are sent alternately to two delivery cylinders, where they are slit longitudinally and delivered on two sets of traveling belts, in signatures of 8 pages each. The machine has thus a capacity of 8 signatures, or 64 pages, at each revolution, or 24,000 signatures per hour, cut and folded, ready for the binder.

The Novel Press.—Similar in its principle of construction to the *Century* press, the

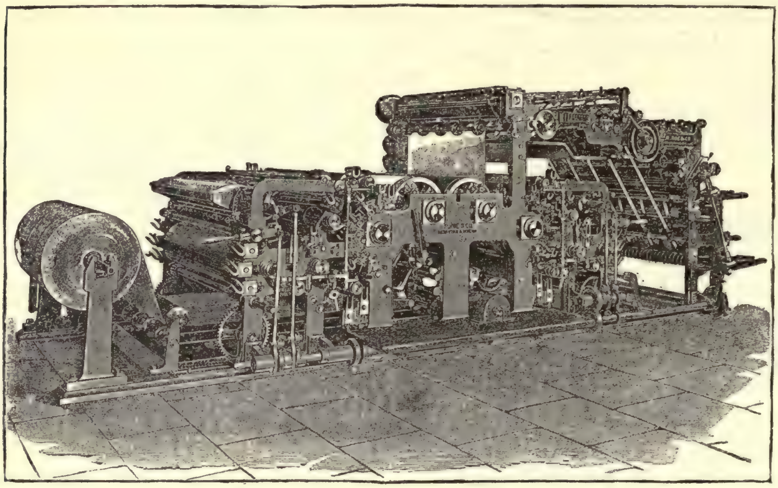


FIG. 2.—The Hoe "Century" press.

Novel press does very difierent work. As its name indicates, it was built expressly for printing novels, and was specially designed to produce in perfected form a great number of pages of these books at each revolution of its cylinders.

The plate cylinders are of the size to contain each 72 electrotype plates, each plate representing a page of the novel. These plates are of the usual thickness and made to fit the curve of the cylinder. The web of paper is drawn into the machine, and receives its impression on both sides. As it approaches the delivery, it meets a cutting-blade which separates the web lengthwise into strips the width of two pages. The strips of paper are taken up by the collecting cylinder until 6 sheets have been gathered. They are then released and cut by rotary knives into 6 equal parts and are delivered to the fly in signatures of 24 pages each, folded to one-page size. There is thus delivered at each revolution a complete novel of 144 pages. The signatures are taken from the fly in consecutive order, and are immediately ready for the binder. This press admits only of 144 pages. If, for example, 216 pages are required for a novel, the plates for the additional 72 pages are placed on the cylinder together with 72 pages of a different book. Thus, while completing one novel, another is begun in the same operation of the machine.

The capacity of this press is 18,000 signatures of 24 pages each, or 3,000 complete novels of 144 pages each per hour.

The Hoe Prudential Press (Fig. 3).—This press is remarkable for the variety of work it will do and for the great number and simplicity of the combinations effected by the folder. It will produce at great speed, sheets of 8, 16, 32, 64, and 128 pages, delivering the signatures in various sizes and folded in pamphlet form. While the general operation of the machine is similar to the Hoe newspaper web presses, it is provided with 2 distributing cylinders and 7 distributing rollers, while 3 five-inch inking rollers and 2 cleaning rollers pass over the form. The electrotype plates are $\frac{1}{4}$ of an inch thick, are bent to the required

curve by a machine for the purpose, and, being held in place on the cylinder by end-clips, they may be underlaid, as on the ordinary flat-bed press.

The press is twice the width of the paper which is used, the whole form of plates being carried on one cylinder. One side of the web is printed from one end, or half, of the cylinder,

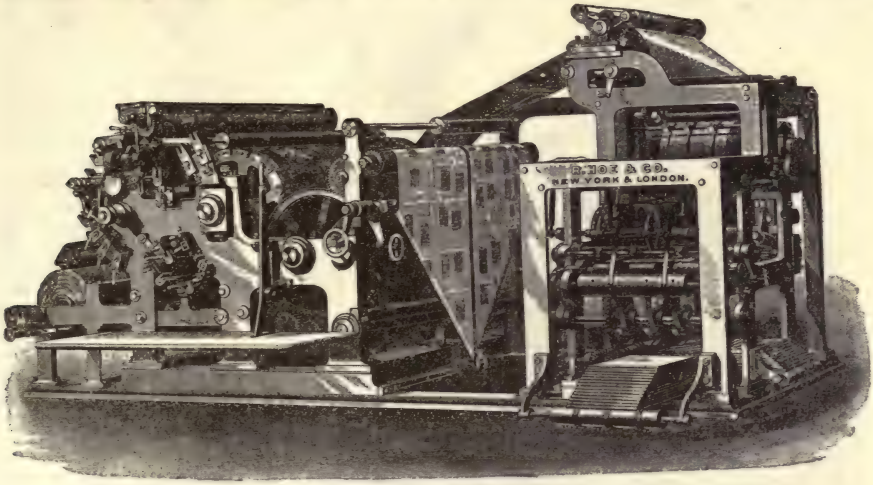


Fig. 3.—Prudential press.

and then passes around a V-shaped transferrer, and back again to receive the impression of the other half upon its reverse side. The folder delivers the sheets, cut and counted in lots of 50, in the sizes and at the rate per hour given below:

Signatures.	No. Pages.	Size Page.
8,000	64	7 × 4½
8,000	64	4½ × 7
16,000	32	7 × 4½
12,000	32	6 × 7
8,000	32	9 × 7
8,000	32	7 × 9
4,000	32	14 × 9
8,000	16	14 × 9
16,000	16	7 × 9

The paper is drawn from a roll at the end of the press, presented to the printing cylinders in the manner described, and after being perfected it passes to the folding machine, where the web is split down the center margin, thus producing 2 webs of one-half the width, which are transformed by collecting and cutting cylinders into signatures of the desired number of pages, and delivered folded in the variety of forms and speeds indicated above. This press is perhaps destined to revolutionize the printing of books and pamphlets, as its great capacity enables it to do the work of a dozen two-revolution cylinder presses and an equal number of hand-feed folding machines.

The Hoe Prudential Press (Fig. 4) is made with flat delivery, when desired, specially adapted to a variety of work requiring long runs. It will print four pages of various widths, while the adjustable knives, by which the paper is cut, allow a variety of commercial printing. It is also provided with a perforating arrangement by which coupon work may be done. Up to the point where the sheet goes to the folder, this machine is exactly like the machine with folder attached, as first described, but the paper is, instead, slit longitudinally, cut transversely, and collected in five thicknesses upon a cylinder from which it is delivered to the sheet flyer and laid upon the table at the rate of 9,000 full-sized sheets per hour. When it is desired to print on only one side of the web, the paper roll is removed to the other side or half of the plate and impression cylinders, and passes between them only once and then direct to the collecting cylinder and delivery, one-half of the impression cylinder being without forms, and the necessary plates being placed on the end of the cylinder which lies in the path of the paper.

Cottrell's Air-spring Two-roller Press.—This drum-cylinder press, made of various sizes, covers the necessities of a large share of work done in nearly every printing office. This press, and also the two-revolution press, contains Messrs. Cottrell & Sons' patent air-spring with governor attachment, which bears on an easy cushion for the bed, and can be readily adjusted for different speeds. This air-spring not only forms a cushion to arrest the

momentum of the bed as it passes the center, but with the assistance of the governor and vacuum valves aids in starting the bed on its return movement, and relieves the gearing of all undue strain. By the governor valve, in the air-pipe connected with both of the hollow piston rods, the amount of spring pressure is controlled, the gate being kept either wholly or partially open or closed, according to the position of the governor balls as affected by the speed of the press.

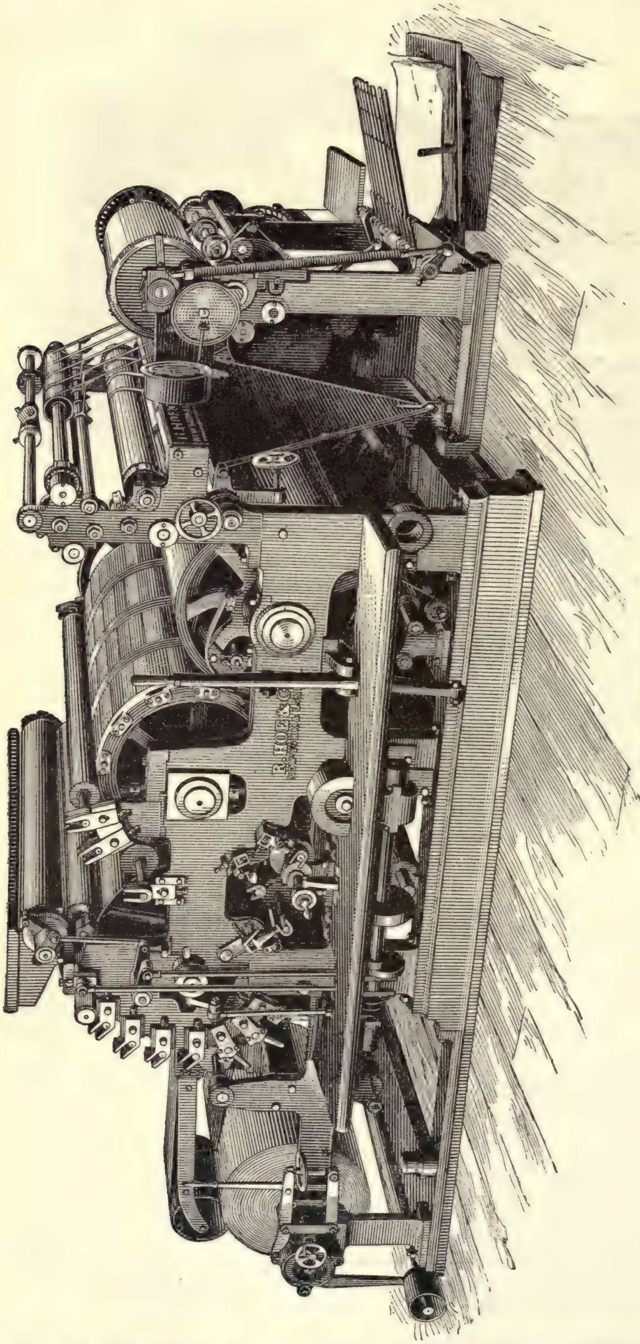


Fig. 4.—Prudential press.

The Potter Flat-bed Perfecting Press (Fig. 5).—This improved press combines the well-known advantages of the Potter two-revolution press and the perfecting press, which print from flat forms, either type or plates, a high-grade work, economically and profitably.

The general mechanical movements of this press are the same as those of the Potter two-revolution press. The driving mechanism and the patented method for controlling the raising and lowering of the cylinders and regulating the impression, are identical with the two-revolution presses. Some of the distinguishing points of this press are:

The feeding and cutting device for roll feed: as will be seen in the engraving, the paper is taken from a roll at the end of the press and led into forwarding rollers, which in turn carry it between the cutting cylinders, thence on through another pair of rollers, which have the web under full control until the sheet is cut and seized by the grippers of the feeding cylinder. The cutting and feeding mechanism, claimed to be the only one by which sheets of various sizes can be cut and carried positively to the grippers: the changes necessary for cutting sheets of different lengths are easily and quickly made, all gears being plainly marked so as to correspond with a graduated scale on the frame. By this means, in connection with an index finger on the adjustable carriage of the cutting cylinders, the relative position of the cutting cylinders to the feeding cylinder, as the size of sheet is varied, is easily deter-

mined and accurately adjusted. The adjustable carriage of the cutters allows tapes to be dispensed with, and ensures positive control of the sheet at all times. The press is not limited, however, to roll feed, but may be fed by hand as well to the same guides, and with no change of mechanism save the adjustment of a simple clutch. The registering segments on the cylinders not only engage with the usual racks on the type-bed, but with each other at each revolution. In addition to this, Messrs. C. Potter, Jr., & Co. have a newly patented device by which the cylinders are driven at all times in full gear, despite their rise and fall, which, combined with their patent bed driving rack, insures accurate register.

The distribution is that of a four-roll, two-revolution press, with rack screw, table and cylindrical distribution. There has been added to the regular table distribution of the four-roller press, the vibrating cylinder and riders of the stop cylinder.

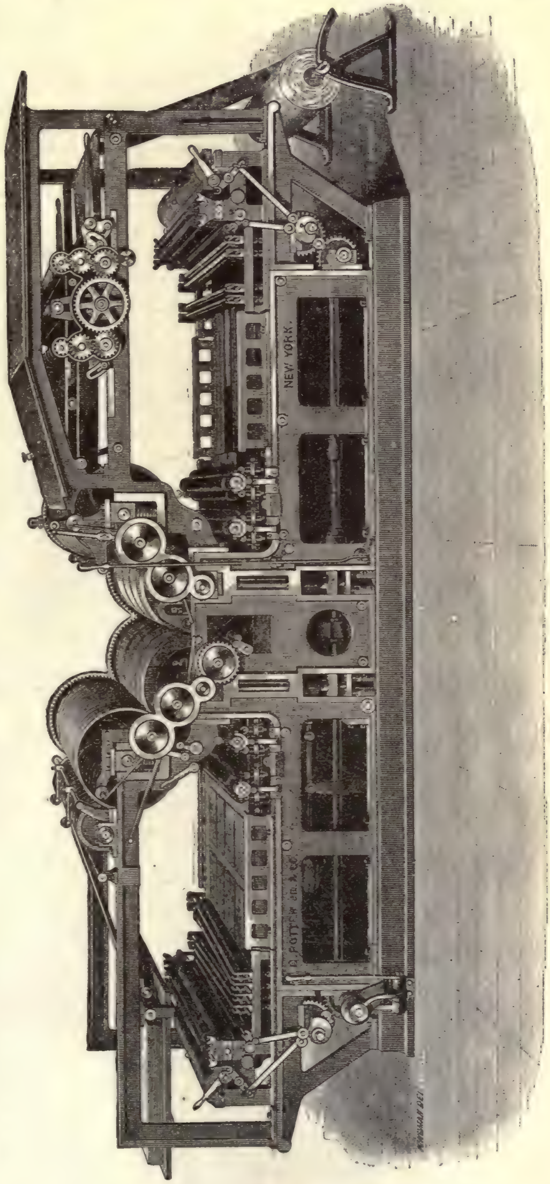


Fig. 5.—Potter flat-bed perfecting press.

Cottrell's Two-revolution Press (Fig. 6).—This press embodies a patent "front sheet delivery," brought out by C. B. Cottrell & Sons. It dispenses entirely with the fly, and no tapes or strings are used in its construction or operation. It takes the printed sheet from the cylinder by grippers, a positive motion, carries it rapidly through the air, and deposits it on the pile table, printed side up, over the fountain. It requires no adjustment for large or small sheets. Another great advantage claimed over other methods of delivery is the convenience with which the forms and rollers can be handled. The rear of the press is, of course, left entirely unobstructed for the placing of forms. The delivery is placed sufficiently high above the bed to be entirely out of the way, and as there are no tapes or strings whatever in front of the cylinder, it will be seen that the forms may be placed or corrected and the rollers easily handled from either side of the machine. The feed-board is so constructed and hinged that it may be lifted entirely away from the cylinder, leaving free access to the whole printing surface, and giving ample room from either side of the press for making ready. This press also has a "power backing-up motion and a trip," enabling the operator to throw off the impression at will, or to roll the form any number of times, and also has a patent reel and fly delivery.

The Cottrell Stop-cylinder Press contains many patented improvements which are distinctive features. The frame is cast smooth inside and out, without flanges. The bed has four bearings under the impression and runs upon hardened steel rollers. A solid girt is bolted to the bed-plate crosswise of the press, and extends up to and supports the tracks, thus making nearly a solid mass of iron directly under the cylinder in line with the impression. The cams for operating the cylinder have been considerably enlarged, thereby imparting an easier

motion to the cylinder when stopping and starting. This change admits of the press being run at a much higher rate of speed. The feed guides have been removed from the feed board, where so many disturbances are liable to affect the register, and have been placed in the cylinder itself and revolve with it. The angle of the feed board has been so changed

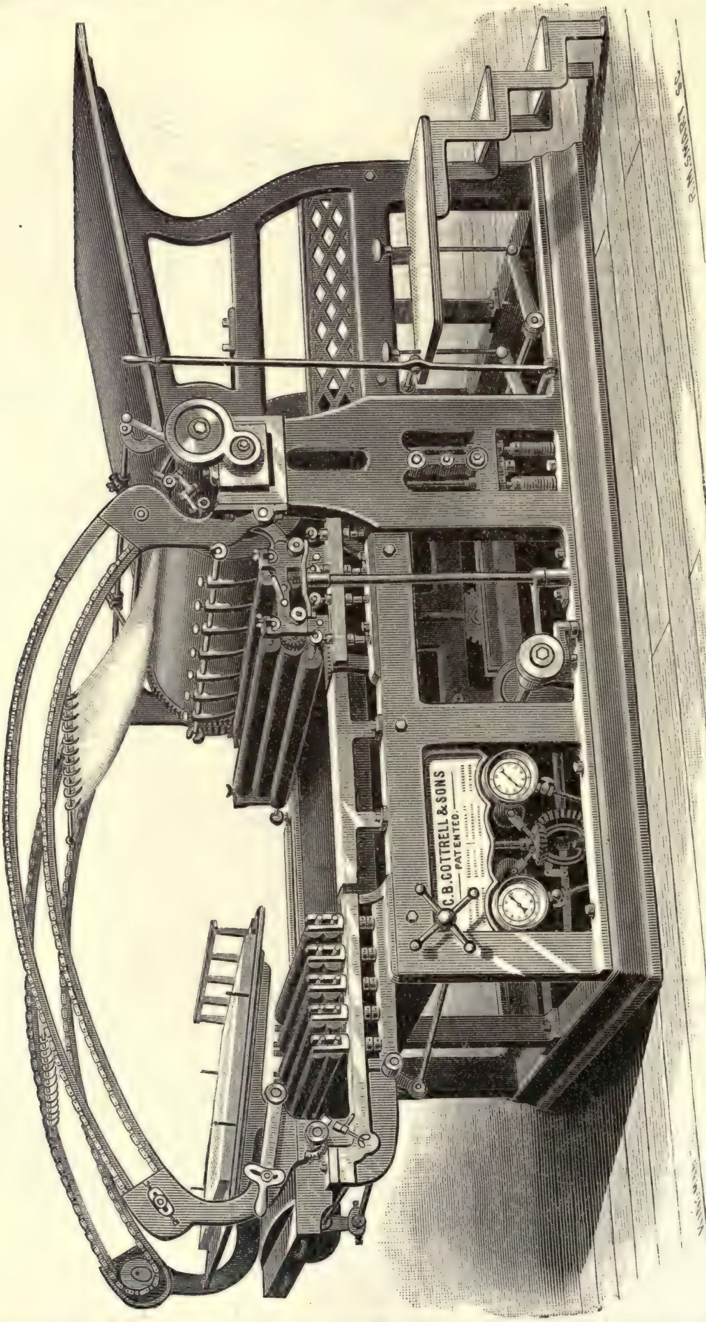


Fig. 6.—Cottrell two-revolution press.

that the sheet is in nearly a horizontal position when fed to the guides, thus preventing any "buckle" in the sheet when the grippers close on it. This press is also arranged with the "trip at will" feature, enabling the feeder to throw off the impression if a sheet is not fed properly to the guides, also enabling him to roll the form any number of times to each impression. By means of a reverse motion, the feeder is able to "back up" the press with-

out leaving his position on the platform. The patent hinged ink-roller frames admit of the vibrators and distributors being easily raised clear of the form rollers, leaving them free for removal. The whole system of rollers can be handled at one side of the press, economizing both time and wear.

Potter's Newspaper Press (Fig. 7).—This quarto and folio press takes paper from a roll, prints from stereotype plates, and cuts, pastes, and folds, as may be desired, at the rate of from 10,000 to 12,000 eight-page newspapers an hour, or double that number of four-page papers an hour. The printing machine, folder and delivery mechanism are all contained in a single frame. The web, printed on both sides, leaves the second impression cylinder and passes directly into the cutting and folding cylinders ; or it may pass over a turning bar and be turned laterally into the folding and cutting cylinders, and thence to the vibrating folder, whence the folded papers are delivered into the packing box, from which they may be readily taken by the pressman. When an eight-page paper is to be printed, the web is split in the center and each half of the web is turned round separate turning bars, so that the two webs are brought one under the other, and in this shape the superimposed webs are led to the cutting and folding cylinders as before. From the nature of the machine, and by a slight change in the arrangement of the mechanism, any variety of product can be produced. Thus, the papers may be folded once or twice; and being folded twice longitudinally, may be folded crosswise; and by duplicating the cylinders for dividing the web, folio sheets can be delivered from the press as readily as can quartos

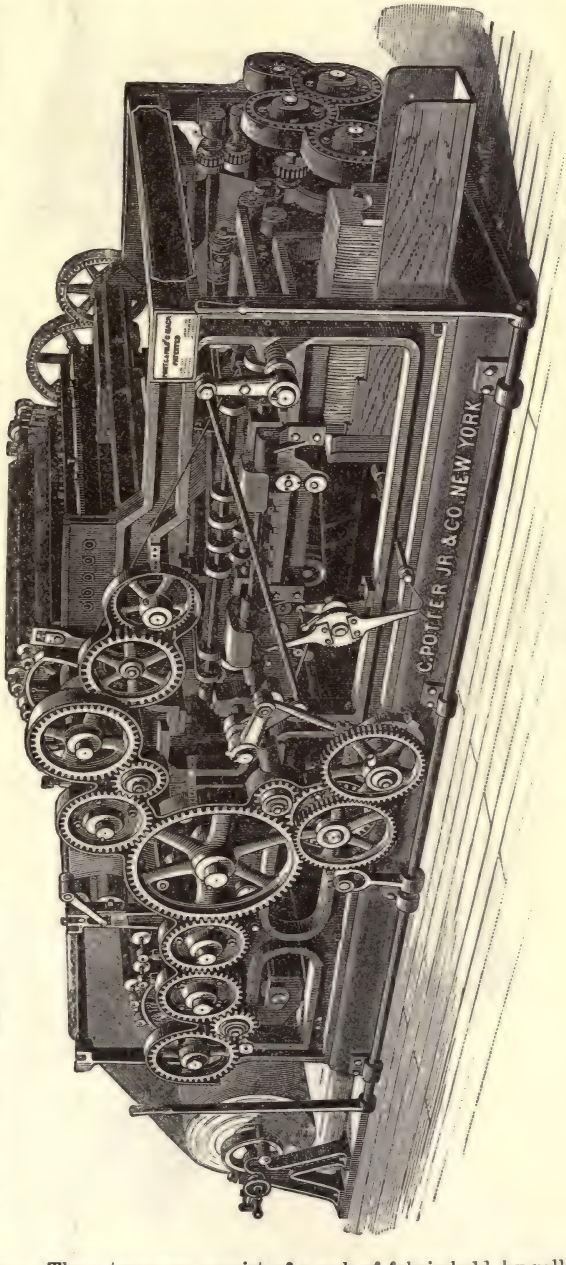


Fig. 7.—Potter quarto and folio press.

A Web Perfecting Press, built by Messrs. Cottrell & Sons, for the *Youth's Companion* newspaper, employs a novel shifting tympan. The press prints from a web of paper that is led between the first type cylinder and the impression cylinder, and thence in contact and between a second type cylinder and a second impression cylinder, which latter is twice the circumference of the first. The second impression cylinder carries two sets of tympans. These tympans consist of a web of fabric held by rolls in the cylinder, which are shifted automatically over the surface of the cylinder the length of a sheet every 50 or 100 impressions, thus presenting an entirely fresh offset surface. The time at which the automatic shifting of the tympan occurs may be regulated to suit the matter being printed, and the extent to which offset occurs in practical use. From the second impression cylinder the web, printed on both sides, is led to a traveling gripper band,

which in turn leads the web between a pair of cutting cylinders to sever it into sheets, and the grippers of the band take the sheet from the cutting cylinders and at the proper time release it so that it may be deposited with the pile on the piling table.

The Hoe Single Web Perfecting Press has two form cylinders, each carrying four pages of a newspaper, printing two complete copies of a four-page paper at each revolution—speed, 24,000 per hour—or the eight plates many be so arranged on the two cylinders as to print one eight-page paper at each revolution—speed, 12,000. Papers are delivered, folded, and counted automatically.

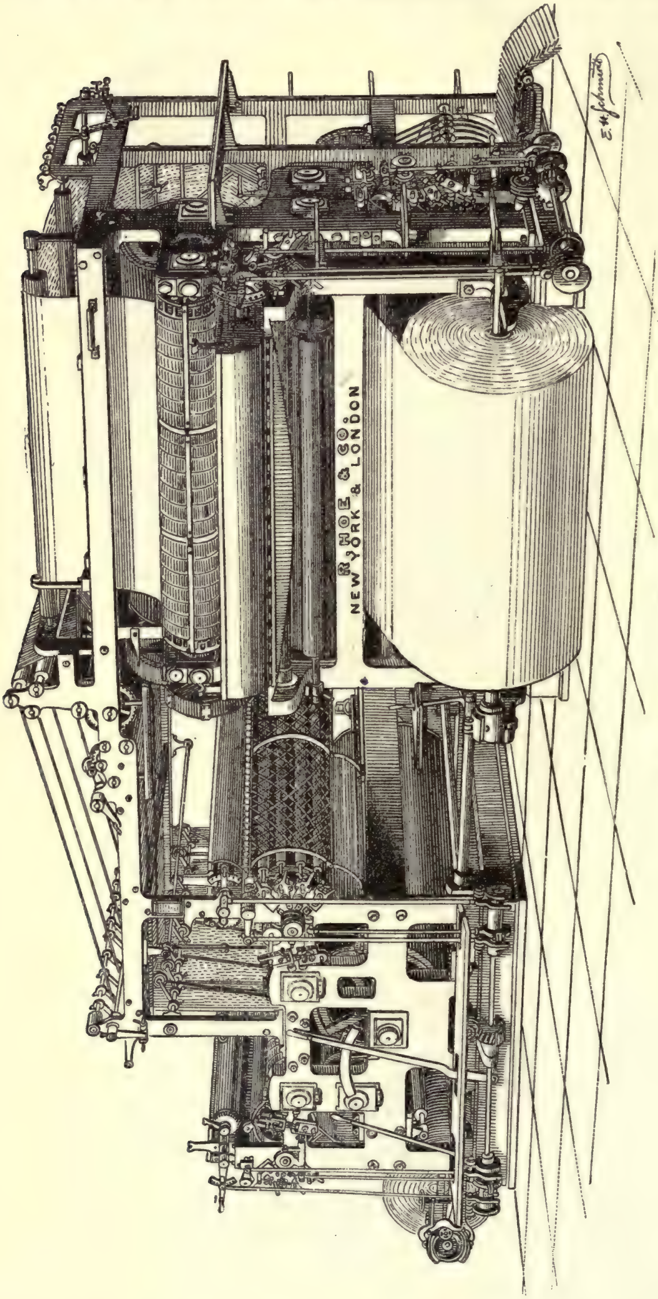
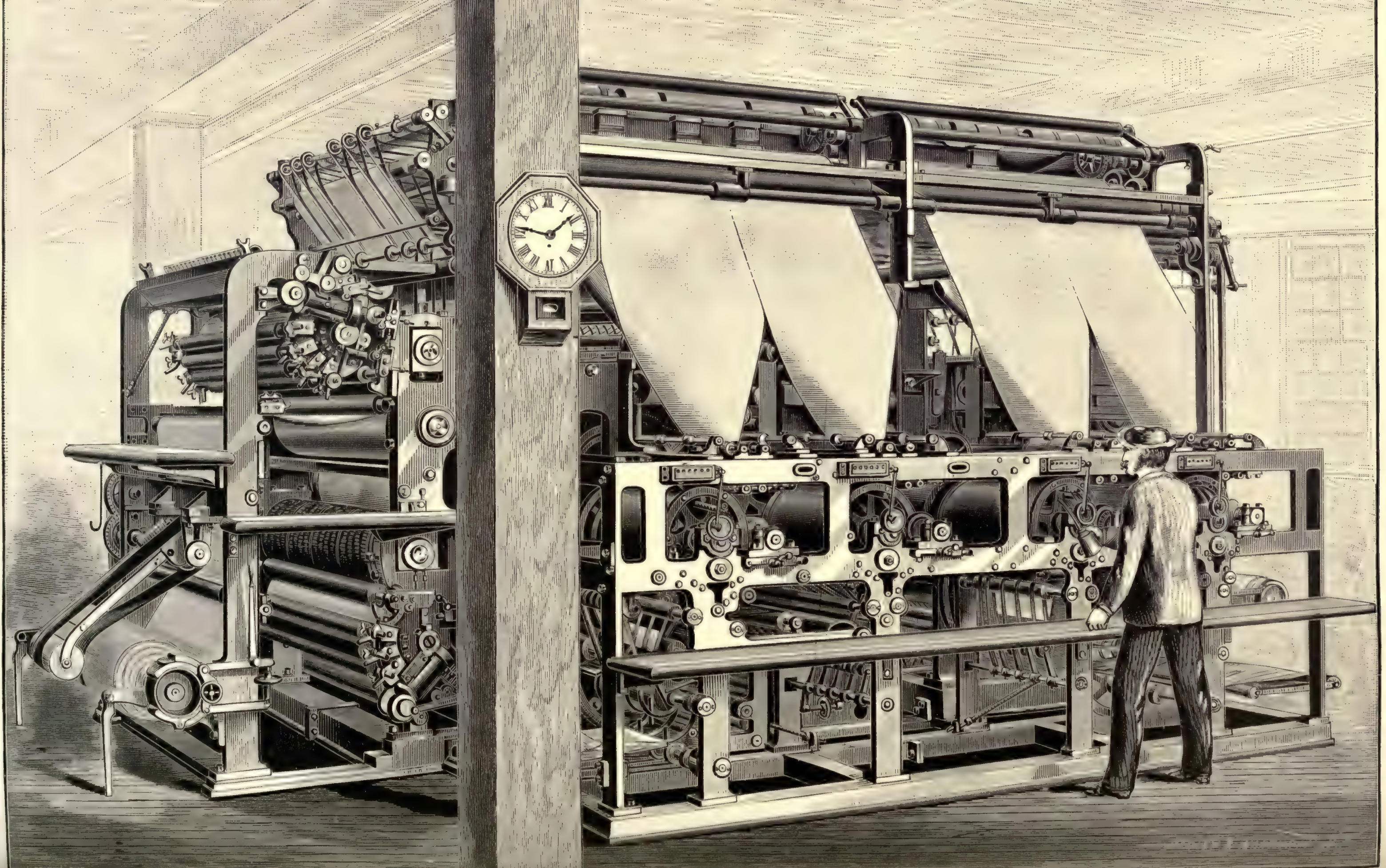


Fig. 8.—The Hoe quadruple press.

The Hoe Three-page-wide Press has two form cylinders, each carrying three plates lengthwise of each cylinder and two around it. The following productions result: From a two-page-wide web, printing from only four plates on each cylinder, 24,000 four-page or 12,000 eight-page papers per hour. From a three-page-wide web, printing the whole width of the machine, 24,000 six-page or 12,000 twelve-page papers per hour; eight and twelve-page papers resulting from the gathering, by means of the Hoe collecting cylinder, of 2 four-page and 2 six-page papers respectively, containing different matter. On this machine the six-page papers are made by slitting the web, after being printed on both sides, and turning the resultant one-page-wide web by means of "turning bars" placed at the proper angle, and so directing it under the two-page wide web, just before it enters the folder, that the single sheet is folded inside of the two-page-wide one and secured down the center margin of the latter by a line of paste. This three-ply web is cut transversely, folded, and delivered exactly as a four-page paper would be.

The Hoe Double Stereotype Perfecting Press has eight stereotype plates on each of the two form cylinders; four plates, lengthwise each cylinder, and two round the circumference.



THE HOE SEXTUPLE STEREOTYPE PERFECTING PRESS, WITH FOLDERS.

This machine has twice the capacity of the Hoe single stereotype press above referred to, and in addition can print six or twelve-page papers at the same speed and in a similar manner to the three-page-wide machine by using a three-page-wide roll of paper. Its total capacity is *48,000 four-page papers* per hour, 24,000 six or eight-page papers per hour, 12,000 twelve or sixteen-page papers per hour.

The Hoe Supplement Presses are composed of a regular double press, with a single three-page-wide or second double press at right angles to it, and a folder receiving the product of both. Either press can be run at partial (as well as full) capacity, by means of narrow paper rolls, and its product associated with that of the other machine, or they can be disconnected and run separately.

The Hoe Double Supplement Press.—The main press is similar to the double press already described (which see) and has the same capacity, viz.: 24,000 four, six, or eight-page papers, or 12,000 twelve or sixteen-page papers per hour. The supplement press is similar in capacity to the single press already described. It has a capacity of 24,000 four-page or 12,000 eight-page papers.

Each press has its roll of paper, and upon the main press roll of all these supplement presses runs the Hoe automatic tension brake for graduating the feed of the paper to the exact speed of the machine, producing a constant and uniform tension. Total capacity of this machine, 24,000 eight, ten, or twelve-page papers per hour ; 12,000 sixteen or twenty-four-page papers per hour.

The Hoe Three-page-wide Supplement Press.—The main press is similar to the double press. The supplement press is of the capacity of the three-page-wide machine, each press being equipped with rolls of paper of suitable width. Total capacity: 36,000 eight-page papers per hour; 24,000 ten, twelve, or fourteen-page papers per hour; 12,000 sixteen, twenty, and twenty-four and twenty-eight-page papers.

The Hoe Quadruple Press (Fig. 8).—Main press and supplement press of the same capacity, each being equal to a double press machine. Two rolls of papers used, and total capacity, 48,000 four, six, or eight-page papers per hour; 24,000 ten, twelve, fourteen, or sixteen-page papers; 12,000 twenty, twenty-four, twenty-eight or thirty-two-page papers per hour, all carefully folded together, and pasted, if desired. All of the folders of these newspaper machines are arranged to automatically count their product in lots of twenty-five or fifty, in convenient shape for handling.

The Hoe Sextuple Press (see full-page plate).—This is a gigantic machine, probably the largest in the world, and unapproached in number of combinations or speed of delivery. Its capacity is estimated at 96,000 four or six-page papers, 72,000 eight-page papers, 48,000 ten or twelve, 36,000 sixteen, 24,000 fourteen, twenty, and twenty-four. This machine, when running at full capacity, prints from three rolls of paper, each about 70 in. wide, and the perfected web is received into a double folder. Besides the great variety of pages possible in the Hoe machinery, all their foregoing presses are so arranged that the pages may be increased or diminished by one or more columns.

Such is the perfection to which the accessory machinery has been brought (for producing the curved stereotype plates for use upon these machines) that a plate can be completed in about seven minutes from the time the stereotypers receive the page set up in type, and additional and duplicate plates may be cast at the rate of one per minute thereafter. Mechanism is also supplied whereby the insetting of supplemental or additional pages can be readily accomplished at will, thus conforming to the exigencies of modern newspaper requirements.

Delivery Mechanism, or Folders.—In applying the principle of rotary printing, the chief difficulty has been found in the designing of devices which would successfully handle the stream of papers issuing from the printing cylinders, and with some makers this is yet practically an unsolved problem. The folders were either so complicated and delicate as to be constantly getting out of order or meeting injury from "chokes" of paper, or were so inaccurate when driven at high speed as to be useless. Until very recently the folders were filled with striking blades for striking the paper in a center margin and forcing it downward into the bite of rollers beneath them, thus producing a fold. Large numbers of tapes were used to guide the papers through the various pathways, which introduced another element of uncertainty, for the least atmospheric change would affect their tension. Messrs. Hoe & Co. have conceived and carried into execution the idea of giving every portion of the folders a rotary movement, driving by a positive motion in due relation with the printing mechanism, so that every revolution of the printing cylinders would actuate the folders in accurate time with them. So perfect are the results they have obtained that in place of the former necessity for having several folding mechanisms of huge dimensions to handle the product of one set of printing cylinders, in the machines of their manufacture one small folding device receives the total output of two or more complete presses.

The Homer Lee Power Plate-printing Machine.—A few years ago Mr. Homer Lee, an expert in the engraving and printing art, after a long series of experiments, finally introduced a plate-printing machine operated by steam power as in ordinary printing presses, in which the engraved plate was mechanically inked and wiped ready for the impression. This press, omitting the wiper cloths, resembles the well-known form of printing press termed "stop cylinder," wherein after the impression takes place the impression cylinder comes to a stop during the feeding of the next sheet to its grippers, while the bed is traveling back idly to be inked preparatory to moving forward again. The frame of this press is extended upward so as to provide bearings over the travel of the bed for the rolls carrying the wiping cloths. These cloths extended from one roll down under what is termed a pad, and then upward to

another roll; the rolls being intermittently moved, one to unroll a small portion of the cloth, and the other to roll up a like portion, thereby presenting a fresh wiping surface below the pad. There are a number of these pads extending transversely across the machine so as to bear the cloths upon the plate as the latter travels beneath them. These pads were given a constant transverse reciprocating motion, so that the cloths were rubbed over the surface of the inked plate as the bed moves forward into the plane of impression with the cylinder. The plate is kept constantly heated by gas jets burning below the bed; and in some cases one or more of the wiping cloths is dampened by passing the cloth through a water trough, the

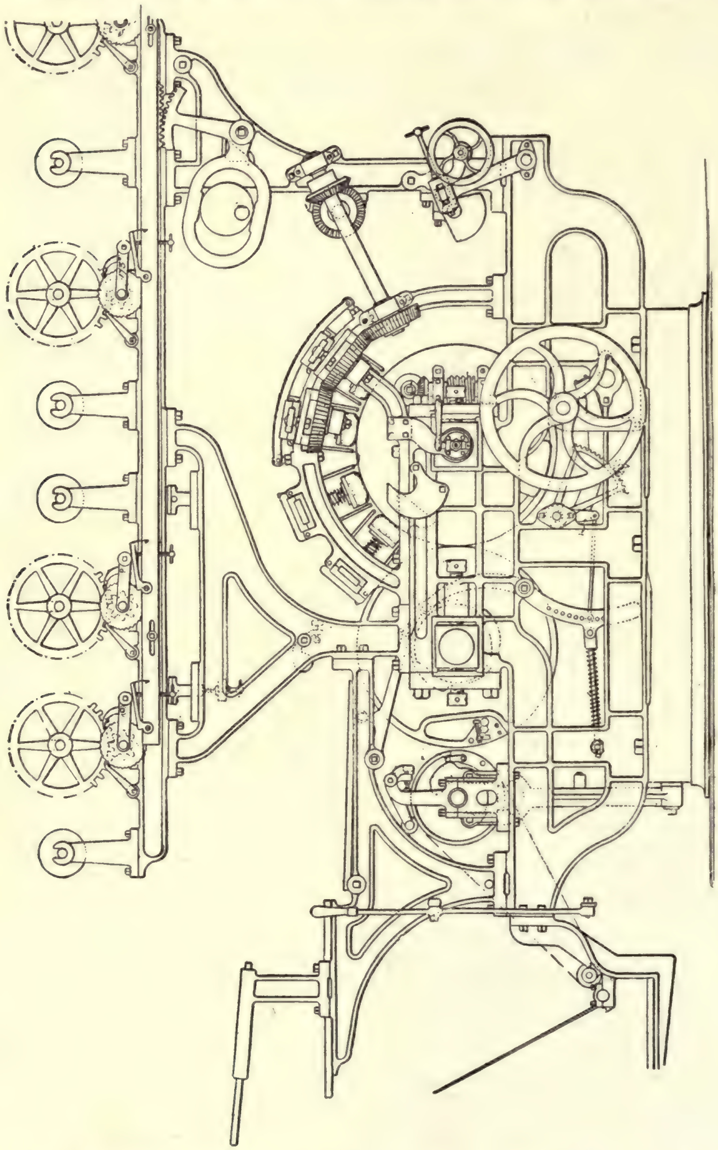


Fig. 9.—Rotary plate-printing machine.

amount of water absorbed thereby being regulated by a squeezing roll; and finally the last pad, or the one nearest the impression cylinder, has or may have its cloth omitted and the chalk applied to its under surface so as to give the final polish to the plate just before printing; the cloth also in some cases is employed with this pad, and in this case the cloth has chalk automatically applied to it instead of to the pad. The sheets to be printed are fed by a girl from the usual feed-board to the grippers of the impression cylinder, and after being printed upon are delivered in the usual manner.

This flat-bed plate-printing machine has met with great success in printing many difficult

plates entirely automatic, and has lately been used by the United States Government with great success for printing the cigar and beer internal revenue stamps, which are considered a very severe test on the automatic inking and wiping features of the machine.

The art of plate printing by machinery was still further improved by the introduction by Mr. Homer Lee of his rotary machine illustrated in Fig. 9. In this machine the plate is carried by one of the cylinders, over which the wiping-pads are arranged, the other cylinder being the impression cylinder, with grippers for carrying the sheet ; and the smaller cylinder is the delivery cylinder, also having grippers which take the printed sheet from the impression cylinder, and thence by the tapes and fly frame is delivered onto the delivery table printed side uppermost. This machine embraces all the various adjustments of the parts necessary to obtain any variation in inking, wiping, impression, and heating of the plate the printer may desire. The pads, in some respects similar to the pads in the other machine, are also rendered adjustable, so that they may exert any degree of yielding pressure upon the plate, and any portion of the pad is equally capable of adjustment, so that the wiping of the plate is absolutely within the control of the pressman. Two of the pads reciprocate transversely across the plate as in the other machine, and the other two have an elliptical motion across the plate, this motion imitating the hand-wiping operation to perfection. The cloths are carried by the rolls arranged at the top of the machine, and are carried down beneath the wipers and back up to the winding-up rolls. In this machine the unwinding rolls are mounted loosely so as to revolve to unwind a portion of the cloth when it is drawn upon by the winding-up rolls, which are all moved in unison, step by step, but to different extents, if necessary, by a reciprocating longitudinal bar that carries short, adjustable inclines, which move under their respective pawls, and thus rotate the connected ratchets and thence the winding-up rolls. This rotary machine has been used recently in printing postal notes for the United States Government, and has printed in one week as many as 70,000 sheets, size 18 × 18 in., containing 8 postal notes with their stubs, which is considered by persons familiar with the difficulties of plate printing by power as a most credible showing.

PRESSES, DRAWING. Sheet Metal.—*Toggle Drawing Presses.*—The most important recent improvement in drawing presses is the perfecting of an arrangement for operating the blank-holder by means of toggles, which entirely dispenses with cams of any description. Two rock shafts are placed across the back and front of the frame, to which the blank-holder yokes are connected by toggle links. These rock shafts are operated from a crank on the outer end of the main shaft, by a peculiar system of link work, which imparts, through the blank-holder, a much more uniform pressure to the blank than can be maintained in cam drawing presses. The strain arising from the pressure put upon the blank is transferred through the straightened toggles directly to the frame of the press, instead of falling on the main shaft, thus relieving entirely the bearings from all friction and wear due to the blank holding. Better and smoother work, with fewer wasters, greater durability, and less consumption of power, are the principal advantages gained through this toggle movement.

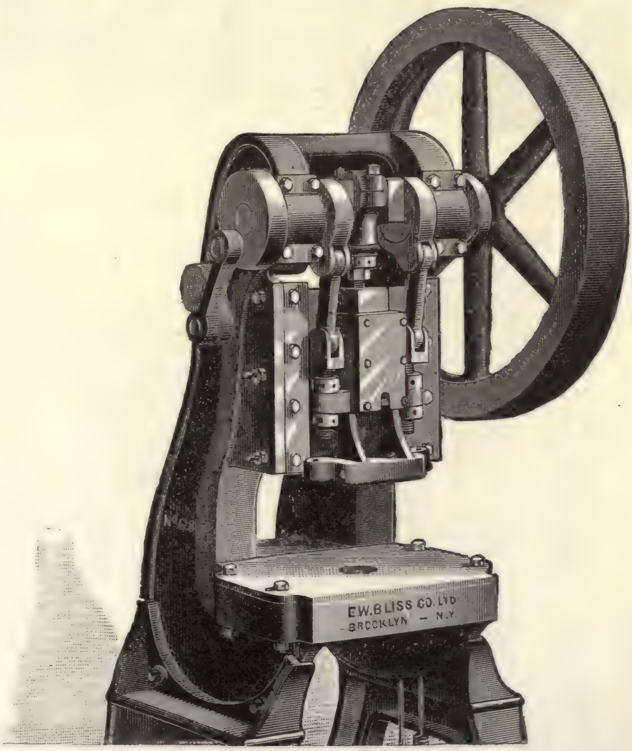


Fig. 1.—Toggle drawing press.

In presses of this type, made by the E. W. Bliss Co., of Brooklyn, N. Y., the main frame of the usual sizes is made of a single casting. The main shaft is of forged steel, with a crank slotted out to operate the plunger. This plunger is guided on the inside of the blank-holder slide and connected to the crank by a pitman with steel adjusting screw, provided with right and

left-hand ratchet collars for quickly adjusting same. The adjustment of the blank-holder is made by means of four steel screws. In the larger sizes, power is communicated to the back shaft through a powerful friction clutch, which, in connection with the automatic brake, places the movements of the press entirely under the control of the operator, so that the press can be stopped and started instantly at any point of the stroke.

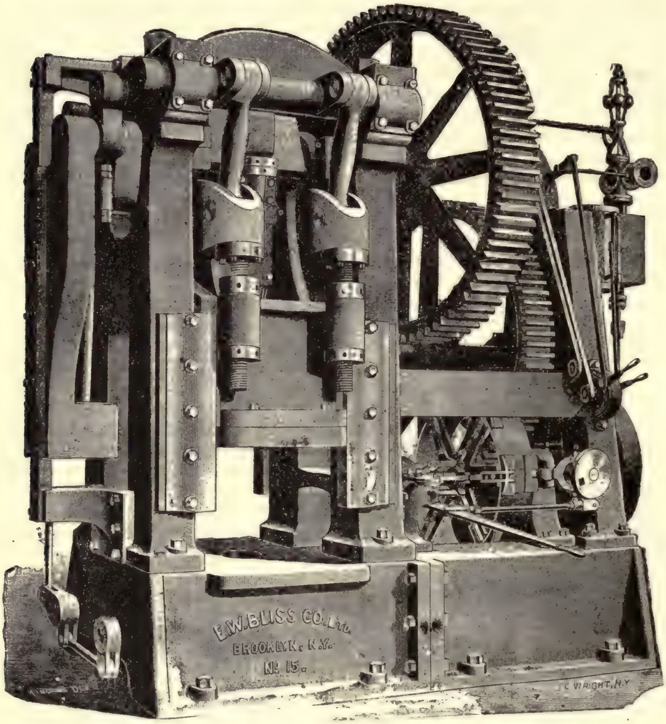


Fig. 2.—Toggle drawing press.

Fig. 1 shows one of the smaller sizes of press made by the E. W. Bliss Co. This press is adapted for operating double-action dies in the manufacture of brass, tin, and other sheet-metal shells not exceeding $3\frac{1}{4}$ in. in diameter or $1\frac{1}{2}$ in. in depth. This includes a large variety of lamp and burner work, tin boxes and covers.

Manufacturers of metal goods of various kinds have discovered that many articles which have heretofore been produced by casting them, or by expensive processes of forging, can be made by the process of cold drawing, provided the proper machine is constructed, and the tools

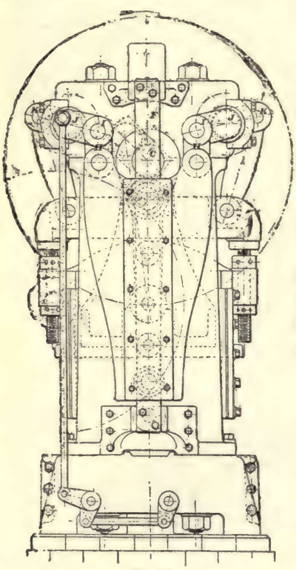


Fig. 3.—Toggle press. Elevation.

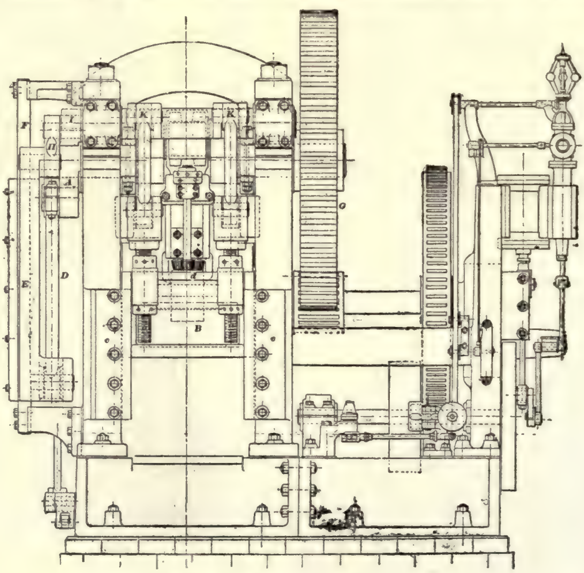


Fig. 4.—Front elevation.

used with it are made with due regard to the behavior of the metal worked in the drawing press. Many comparatively thin and light articles, which have heretofore been cast, are

now being drawn out of sheet metal, and the drawing process is found to have so many advantages peculiar to itself that the limits within which it is applied are constantly being extended.

A recent example is afforded by the machine shown in Fig. 3, designed and built by the same corporation to be used in drawing the common kitchen sink out of sheet steel, instead of casting, as has hitherto been the practice. The machine is remarkable in respect to the size of blank it will work; its great power and strength; in having an engine directly attached for driving, and in many of its features of construction. Fig. 2 gives a general view of the machine, and Figs. 3 to 8 show some of the details of construction and method of operation; Fig. 3 being a side view; Fig. 4 a front view from the left of the machine; Fig. 5 a sectional plan; and Fig. 6 a side view from the right of the machine.

The machine consists essentially of a heavy base in two parts, upon one of which is the upright engine for driving, and the clutch mechanism, while from the other portion rise the uprights upon which are the guides for the blank-holder, and which support the crank shaft and other mechanism seen at the top of the machine. The uprights are connected at the top by a heavy beam, which crosses from one to the other above the crank shaft. They are not subjected to tensile stress during the working of the machine, this stress being borne by the four bolts, *b*, *b*, *b*, *b*, Fig. 5, which are 5 in. diameter, and pass through the uprights from the base of the machine to the top, nuts being fitted at top and bottom. The engraving shows the machine with the die removed, but it will be understood that this is secured to the base of the machine between the uprights, and may be of any desired form for the work to be done, and blanks up to 60 in. by 38 in. can be worked. At the four corners of the uprights are the guides for the blank-holder, *B* (Figs. 4 and 5), these guides being formed in part by the plates, *c*, *c*, *c*, *c*, which are bolted to the uprights. To the inner sides of the blank-holder are secured by heavy bolts the two guides, *g*, *g*, upon which the punch-slide works. The latter slide derives its motion from the crank shaft, *C*, Fig. 3, which, driven at a uniform speed by means of the large gear, *G*, imparts to this slide a motion analogous to that of the piston of an engine.

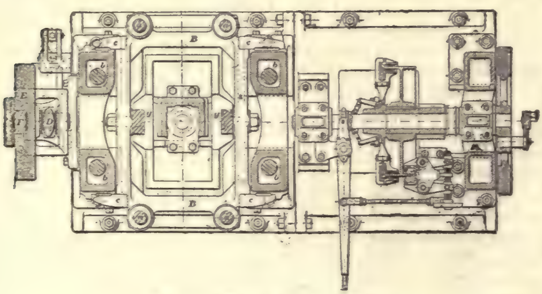


Fig. 5.—Toggle press. Plan.

At the left of the machine, attached to the crank shaft, is the crank, *A* (Fig. 4), which by means of the connection, *D*, gives vertical motion to the sliding piece, *E*, which works upon the angle guide, *F*. At the top of the sliding piece, *E*, and at either side, are connected the short links, *H* (Fig. 8), by which motion is imparted to the cranks, *I* (Fig. 4), these in turn actuating the two auxiliary crank shafts, *J*, *J*, which pass along at either side of the main shaft, *C*, and by means of the cranks, *K*, *K*, and their connections, give motion to the blank-holder slide. These various connections operate to make the "dwell" of the blank-holder shown by the diagram, Fig. 7, at the time the sliding piece, *E*, is at and near the upper limit of its motion, and while the slide carrying the punch is near the lower limit of its motion, which is when the actual drawing of the blank is being done. The diagram, Fig. 7, at the left shows the positions of the various parts when the sliding piece, *E*, is at its lowest point, and the blank-holder raised to its extreme height, while the diagram at the right shows the various positions when the dwell of the blank-holder is just beginning, the small movement of the sliding piece *E*, during this period, acting simply to swing the connections, *H*, *H*, upon their centers, as shown by the dotted lines, but producing no perceptible movement of the blank-holder, while the cranks, *K*, *K*, and their connections being in the same straight line, which is the line of thrust, the moving parts are relieved of all strain, thus avoiding undue wear, and making the full power of the machine available at this time, just when it is needed for the punch. One object in making the piece, *E*, so heavy is that it may act as a counterbalance for the other moving parts. In operation, the blank, which has previously been punched or trimmed to the desired size and shape, is placed over the die, and the blank-holder then first descends in advance of the punch until it rests upon the blank, and exerts a heavy pressure all around its outer edge. The punch then descends and forces the middle portion of the blank into the die, drawing the metal out from between the face of the die and blank-holder, which

Fig. 6.—Toggle press. Elevation.

by its pressure prevents any kinking or buckling of the sheet. It is important to secure even pressure all about the blank, and this is provided for by making the blank-holder in two parts, and putting in the four screws, *a, a, a, a,* one of which being placed at each corner of the blank-holder, and provided with suitable nuts, the pressure can be made uniform all over the face of the die. These screws serve also for the vertical adjustment of blank-holder to suit different dies, the range of adjustment provided for being 8 in. The punch can also be adjusted vertically by turning the shaft carrying the pinion, *d* (Fig. 4), which engages with the bevel gear shown, this bevel being at the bottom of a large screw which affects the movement by means of a slide ; the four bolts, shown above the pinion and on either side of the shaft, binding all tightly together when the proper adjustment has been made, so that no alteration can take place without first loosening them. The extent of this movement is 6 in. The long connecting-rod at the left of the machine, and extending from near the top to the bottom, gives motion to the device within the base, by which the blank is forced up out of the die when released by the blank-holder. The main crank shaft, *C*, is 11 in. diameter, the gear which is keyed to it at the right being 7 ft. 7 in. diameter, 12 in. face, and 4 in. pitch. It is driven by a pinion on the intermediate shaft, the large intermediate gear being driven by a pinion, which is not keyed directly to the engine crank shaft, but to a sleeve which forms a portion of a Hill friction clutch, by which the motion of the press is controlled, a small movement of the lever starting or stopping the press promptly and smoothly, the clutch being so arranged that the movement of the lever which releases it applies a brake, which promptly arrests the motion, and thus the press can be handled with the greatest facility.

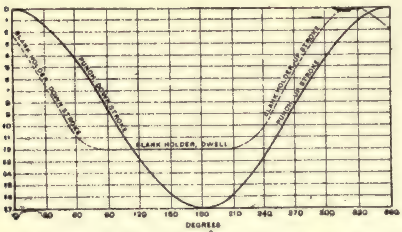


FIG. 7.—Press diagram.

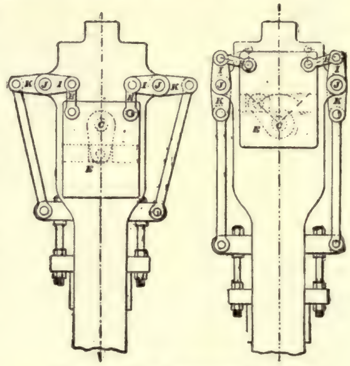


FIG. 8.—Toggle press. Details.

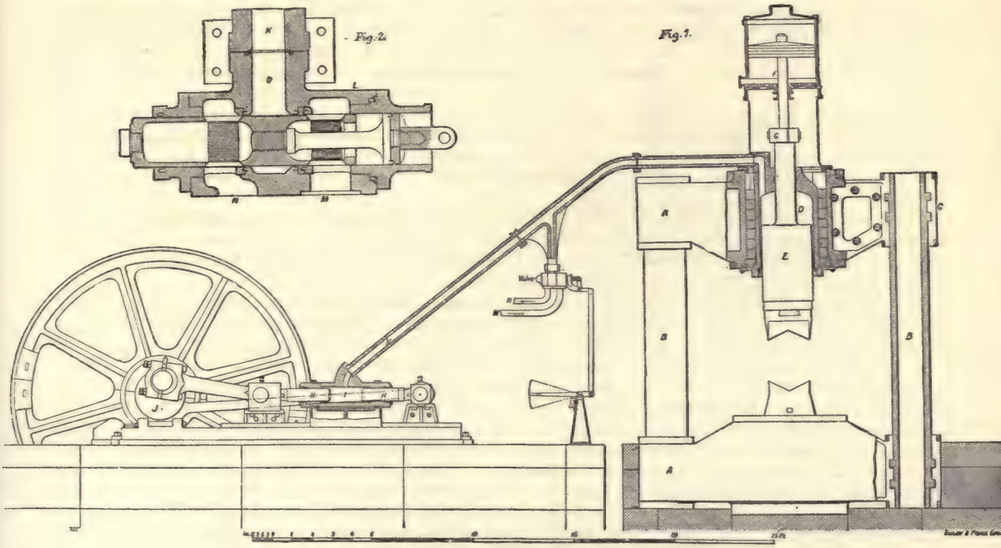
The engine is of simple construction, has a plain slide valve with throttling governor, and has the crank-pin for actuating the valve fixed to a disk, which is at the end of a return crank attached to the main wrist-pin. The disk is so mounted upon the return crank that when the engine is turned in either direction by hand, the disk so adjusts itself by turning on its center that the valve is set for running in the direction in which the engine has been turned, without any further attention being required. The cylinder of the engine is 12 × 14 in. and it is designed to run 250 revolutions per minute, which gives the machine a speed of 5 strokes per minute, the gearing being proportioned 50 to 1. The press stands about 14 ft. high and weighs about 60 tons.

PRESSES, FORGING. *Hydraulic Forging.*—Mr. W. D. Allen, in a paper read before the Iron and Steel Institute in 1891, describes as follows a hydraulic forging press which has been in operation some time in England, and has proven to be a most efficient and useful tool. In this press the force pump and the large or main cylinder of the press are in direct and constant communication. There are no intermediate valves of any kind, nor has the pump any clack valves, but it simply forces its cylinder full of water direct into the cylinder of the press, and receives the same water, as it were, back again on the return stroke. Thus, when both cylinders and the pipe connecting them are full, the large ram of the press rises and falls simultaneously with each stroke of the pump, keeping up a continuous oscillating motion ; the ram, of course, traveling the shorter distance, owing to the larger capacity of the press cylinder.

The press and pumps are shown in Figs. 1 and 2. The top and bottom portions of the framing, *A A*, are alike. The main columns, *B B*, are hollow. The large press cylinder, *D*, is fitted and held in the top frame; the anvil block rests in the bottom frame. *E* is the main ram. *F* is a steam-cylinder with piston, the piston-rod of which is attached to the shank of the ram. *G* is a cross-head working in guides, thus preventing the ram from turning round.

The force pumps are "duplex," the ends or faces of the two plungers, *H H*, advancing and receding to and from each other simultaneously at each stroke. They work into opposite ends of the pump, *I*. This cylinder is simply a strong tube. The two plungers are worked by a three-throw crank, *J*, the two side throws of which are on exactly opposite centers to the middle throw. The two side throws give motion to the plunger furthest from the crank, in which case the strain exerted is a pull, whilst the middle throw gives motion to the plunger nearest to the crank, and the strain is a thrust or push. As before observed, a free communication is at all times maintained between the pump cylinder and the press cylinder. This is done through the pipe, *K*, and when all are full of water and the engine working, an ascending and descending motion is imparted to the press ram at each revolution of the crank, the

descending motion being given by the press plungers, *H H*. advancing toward each other and forcing the contents of the pump cylinder into the press cylinder, the ascending motion taking place by means of the steam-piston, which, on the return stroke, raises the ram, and forces the water back on to the pump plungers as they recede from each other; so that as long as there is no waste of water by leakage, and its quantity is not increased or decreased, the press ram will continue to oscillate at the same distance from the anvil, and could only operate on work of that exact size. The ram has therefore to be raised or lowered to suit the various requirements of work in hand, and to effect this a source of supply of water under a pressure of about 250 lbs. has to be provided, which, when admitted into the press cylinder, has sufficient force to overcome the power of the steam in the steam-cylinder, sending the steam back into the boilers. By this means the ram is rapidly brought down any required



FIGS. 1 and 2.—Hydraulic forging press.

distance; on the other hand, the power of the steam immediately raises the ram upon the water being allowed to escape.

The valve used for the rapid admission and escape of water becomes, therefore, rather an important feature, and is shown in Fig. 2. It consists of a cylindrical facing, having a hollow cylindrical valve or plunger, working endwise through hydraulic leathers; at each end of this valve or plunger very fine slits are sawn lengthwise through its sides or walls, for allowing of the admission and escape of water, by moving the valve endwise until the fine slits pass the hydraulic leather; the set of slits at one end of the valve being for the admission of water, and those at the other for the escape. *L* is the casing bored through and fitted with hydraulic leather, shown in section. *M* is the inlet, *N*, the outlet, and *O*, a passage into the pipe, *K*. The valve is capable of being easily moved endwise. It is hollow, with a solid division in the center, the hollow portion forming a sort of cup on each side of the solid part, and through the side walls of these cups the fine slits are cut. When it is desired to bring the press ram down, the valve is moved endwise to the left until the fine slits pass the hydraulic leather, and a passage is thereby opened from the inlet, *M*, through the slits, and water is admitted into the passage, *O*, and then on to the pipe, *K*, and the ram at once descends. When it is desired to raise the ram the valve is raised to the right, and water passes out through the other set of slits, and away by the outlet, *N*, and the ram at once ascends by the action of the steam. At the time the slits pass the leather the low pressure only is in operation, and at the moment of impact of the ram upon the work the valve is always in its neutral position, the position

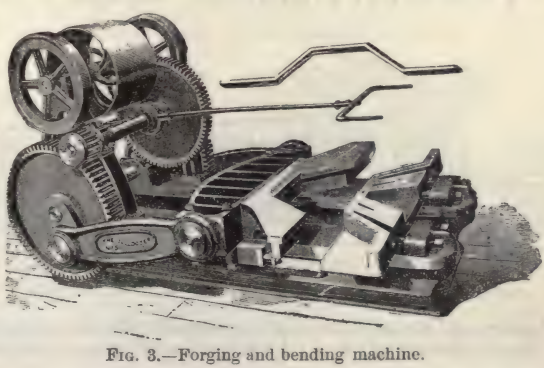


FIG. 3.—Forging and bending machine.

shown in the diagram, the plain body of the central portion of the valve, with a cup leather on each side, being all that is exposed to the great pressure.

The press ram makes a stroke of $2\frac{7}{8}$ in., and its diameter is 30 in., so that at a pressure of 3 tons per sq. in. (deducting the area of the shank) we have a power of 1,700 tons.

A Forging and Bending Machine, of novel form, made by Williams, White & Co., of Moline, Ill., is shown in Fig. 3. The cut shows it as arranged with dies for bending arch bars for freight cars. The machine is a horizontal press, of massive proportions, adapted to be used with a great variety of forms and dies which can be changed at pleasure. The cross-head moves back and forth on the bed. The pitmans are driven by wrist-pins attached to the main gears, of which there are two—one on each side of the bed. By this method both ends of the cross-head move the same distance in the same time.

Forging Compressed Steel for Guns, Shafts, etc.—In order to overcome the want of soundness in steel when cast and forged in large masses, Sir Joseph Whitworth, at his works near Manchester, Eng., introduced the system of consolidating the steel ingots while fluid under hydraulic pressure, and then forging them on a mandrel by a hydraulic press.

A gradually increasing pressure up to 6 or 8 tons per sq. in. is applied, and within half an hour or less after the application of the pressure the column of fluid steel is shortened $1\frac{1}{2}$ in. per foot, or one-eighth of its length; the pressure is then kept on for several hours, the result being that the metal is compressed into a perfectly solid and homogeneous material.

The same system has been recently adopted by the Bethlehem Iron and Steel Works, U. S. A., and by a number of works in England. Open-hearth steel is generally used. The mode of working is thus described by E. H. Carbutt, in his presidential address before the Institution of Mechanical Engineers in May, 1887:

An ingot of the requisite size up to 65 tons is cast either round, or square, or hexagonal, according to the views and experience of each steel maker. The hexagonal form, with sides slightly curved concave, is preferable, because the sides can then follow the shrinkage of the material in cooling, and thus prevent internal rupture of the metal. The ingot, being upright during casting, is cast longer than necessary, so as to get the effect of a head to allow for the steel shrinking as it cools; the head is afterwards cut off in a lathe. The ingot in cooling drives the carbon to the center, so that when cold it is found that although the steel on the outside is mild enough for a gun forging, the center is hard enough for tool steel, containing 0·8 per cent. of carbon. This hard center is then bored out of the ingot, until the test shows that the inside of the annular ring contains the same percentage of carbon as the outside. The center being bored out allows an internal, as well as an external, examination of the ingot. The hydraulic press is then brought into play on the annular ring, with the full advantage of being able to forge on a mandrel. The amount of material which is cut off and bored out of the ingot is so large that it leaves the forging only one-half to two-thirds the weight of the ingot. This loss of material accordingly adds to the cost of the forging.

The hydraulic forging presses vary in power, working at $2\frac{1}{2}$ to 3 tons pressure per sq. in., and having steel cylinders from 35 to 40 in. diameter, with $4\frac{1}{2}$ to $7\frac{1}{4}$ ft. stroke. In several of them the head which contains the cylinder is movable, so that in forging a large mass the cylinder is lifted up and only a short stroke is necessary. The presses are worked direct by large pumping engines, without the intervention of an accumulator, the engines running only while the press is at work. The cranes all have an arrangement for turning the porter-bar, so that the forging is rotated between the blows of the press. There can be no question that the introduction of the hydraulic forging press has been a great means of overcoming the difficulty of making large steel forgings. The pressure is so great and so equal throughout that the steel in the center of the ingot is worked at the same rate as the outside; that is, while an ordinary steam hammer would draw the outside only and leave the centre unworked, thus bringing about internal strains in the steel, the press acts on the whole mass equally throughout.

PRESSES, HAY AND COTTON. *Hay-baling presses* are operated by steam-power or by

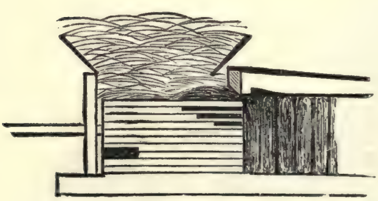


FIG. 1.

The Dederick press.

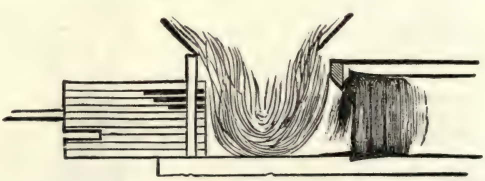


FIG. 2.

horses, and are made in some variety, but all on the plan of compressing small charges in detail consecutively into a long, horizontal, square-cornered box by strokes of a reciprocating

traverser. Fig. 1, which represents the Dederick press, shows the bale begun, the traverser shot home, an overlap of hay from the charge last before pressed, and a fresh charge in the hopper above. Fig. 2 shows the traverser withdrawn, the overlap of hay folded down by the spring top to level the top face of the bale, and the fresh charge of hay rammed down to receive the next stroke of the traverser. Fig. 3 is a section of the bale of hay as it may be peeled from the end of a completed bale convenient for feeding. Fig. 4 is a complete bale ready to ship. While the bale is compressed in the press-box of the machine, several metal ties or bale bands are passed around it lengthwise, but transversely to its series of layers, and along grooves on the inner faces of the compressing surfaces of the movable bulkheads in the press-box, and the ends are then looped and fastened to retain the mass in a firm parallelopiped of convenient size and dense enough to load railway cars to their weight capacity. Numerous ingenious bale ties have been invented for this purpose. One of the latest and best devices is that devised by Mr. J. Wool Griswold, and manufactured by Griswold Bros., of Troy, N. Y. The bale band is of wire, having in one end an eye in which is received thimble-fashion a V-shaped saddle. After the band is put around the bale, the end is passed through the saddle. When strain is applied, the wire jams in the angle of the saddle, and at the same time the saddle being compressed in the eye, closes tightly upon the wire. Fig. 5 is an improved form of hay press constructed of steel. The loose hay is introduced as fast as a man can pitch it into a self-feeder, and, when tied, is emitted at the open end. The duty is claimed as 20 or 30 tons a day, according to power applied. In the Whitman hay-baling press, the plunger rebounds automatically after each operative stroke. The horse makes a tour to

Fig. 3.—Bale section.

Fig. 4.—Hay bale.

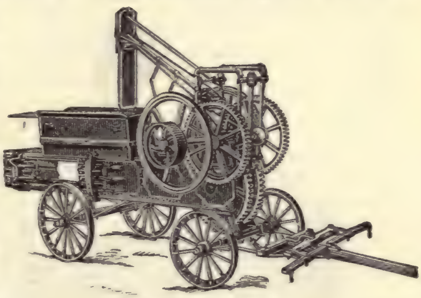
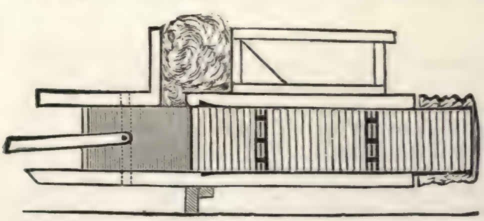


Fig. 5.—Hay press.

Fig. 6.—Hay-baling press.

press each charge of hay. The latter is introduced by an attendant, when the trap-door (seen in Fig. 6), on top, automatically falls open. The plunger, automatically released by a latch,



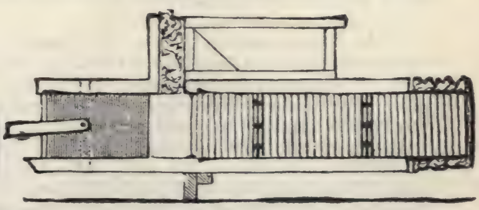


Fig. 7. Cotton-baling press. Fig. 8.

is thrown back to initial position by the expansive force of the compressed hay, providing an empty space in the press-box for receipt of a fresh charge. The bales may be made any-

where from 1 ft. to 5 ft. long. With one horse 6 tons, or with two horses 8 tons, may be baled in a day. The bales made by these presses load and stow with economy of labor and space, and in use the layers of hay are neatly separable. Recent rapid adoption of high-speed, reliable hay-baling presses has caused a decided change in methods of handling the great hay crop of the country, by making it an extremely available shipping commodity, extending areas of consumption, and steadily shifting areas of production westward in the United States, to the prolific, grass-growing prairie regions where the broad, level stretches of land are peculiarly suited to the use of machinery.

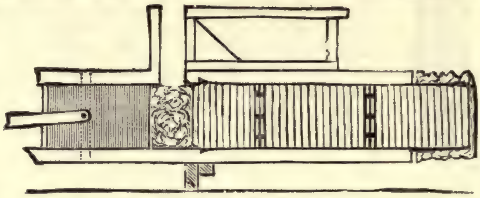


FIG. 9.—Cotton-baling press.

Cotton Press.—Dederick makes a press on the same detail ramming plan, for baling cotton on the home plantation or elsewhere. Its operation is exhibited in Figs. 7, 8, and 9. It does away with the usual necessity of re-pressing for ocean shipment, as it produces extraordinarily condensed bales, straight-edged and flat-sided, without bilge or any expansion when released. As compared with cotton treated by the customary pressing and repressing, claims are made that the fiber of the cotton pressed in the Dederick press is less crushed, as the detail compression admits of a lower maximum of pressure, and that the work is more rapidly done and is less expensive. The capacity of a press is 400 or more of "quarter" bales daily. The average weight of a bale is 125 lbs., and measurement $12 \times 15 \times 30$ in. $=5,400$ cub. in. The ordinary 500-lb. bales, to be equally condensed, would measure but 21,600 cub. in., whereas they are stated as a matter of fact to exceed 33,000 cub. in., average, even after repressing. It should be added that the new quarter bales come apart, when opened at the mill, in sections suitable for the picker. They may, if desired, be ejected by the press directly into sacks or covers. Fig. 10 illustrates size and shape of a "quarter" bale in comparison with a man.

FIG. 10.—The "quarter" bale.

PROJECTILES. (See also, ARMOR; ORDNANCE; GUN, PNEUMATIC.) *Material.*—A little more than twelve years ago chilled cast-iron projectiles were considered all that could be desired for work upon the wrought-iron armor of that period, and, in fact, an extensive series of experiments made in England tended to prove that against this type of armor the chilled iron was fully equal to the steel shell in normal, while it was slightly superior in oblique fire. These experiments also included tests of chilled-iron projectiles against steel plates, with the result of a decision being reached that "steel shell are absolutely necessary for the attack of steel-faced armor." France and Germany were the earliest in the field with steel armor-piercing projectiles.

In the first-named country several concerns are engaged in shell making, each practicing some special mode of treatment, or using some particular chemical combination. At Terre Noire, for example, the steel is oil hardened, but not forged, and the quality varies in different projectiles, being softest in the largest calibers; but the degree of hardening varies also, so that the final product possesses nearly the same degree of hardness in all cases. St. Chamond projectiles are generally made of crucible steel, forged, and oil hardened; but here the quality of the steel is the same for all calibers, and the hardening process differs. That for the 34-cmt. shell is described as follows: The projectile is brought to a cherry-red heat throughout, plunged in oil, and kept immersed until cold; it is then brought again to a cherry-red and dipped in cold water as far as the front band, where it is kept eight or ten minutes; finally it is wholly immersed in oil until cold.

Krupp projectiles are of crucible steel, and the final process is oil hardening; it is said that a file will not bite anywhere on the surface. The use of steel has lately been

extended to the manufacture of common and shrapnel shell also; the thickness of the shell walls is thereby greatly reduced, while retaining all the strength of the cast-iron projectile, so that the interior capacity for bursting charge or bullets, and consequently the efficiency of the shell, has been correspondingly increased. The projectiles are generally made of cast-steel, but in England the difficulty of procuring sound small castings led to the introduction of forged steel for the smaller calibers, and the superiority of these over the cast-steel ones was so marked that they are now made for all calibers.

In this country cast-iron shell have been produced with facility at the various government establishments for a number of years. The efforts to obtain cast-steel shell were long unsuccessful, the first samples being all rejected on account of imperfections in castings. For the past two years, however, the specimens submitted have passed inspection, and the certainty of the necessary supply is now guaranteed. An attempt has also been made to produce chrome steel of domestic make suitable for armor-piercing projectiles, but nothing altogether satisfactory resulted until quite recently. Now it is thought that in the Carpenter projectiles, by adopting methods of manufacture that originated in this country, rather than those that are used in France, the requirements of the French standard have not only been reached but surpassed. The armor-piercing projectiles are all carefully turned and gauged, which renders them very much more expensive than common shell.

Armor-piercing Projectiles.—The armor-piercing projectiles of the Holtzer and Firminy processes have been used in all of the principal armor-plate trials, and are still considered unequaled by England, France, Russia, and Spain. With these sharp-pointed projectiles the only object sought has been penetration on normal impact, and but little attention has been given to the effects of blows delivered at sharp angles. The most important tests of such effects were carried out several years ago at the naval ordnance proving ground with projectiles having heads of various shapes, but as yet the results have apparently been put to no practical use. The decided results obtained at late armor trials have caused some little discussion as to the practicability of using flatter-headed projectiles for oblique attack on armor.

The devices used for securing rifling have undergone various changes during recent years, as the muzzle-loading methods have been forced to give way to the more modern breech loaders. Studded projectiles having buttons or flanges, which followed the grooves in the gun, were very popular abroad, whereas in this country we preferred expanding rings at the base of the projectile. These rings carried an annular groove in which the powder gases acted in such a manner that they forced the outer portion of the ring into the rifling grooves, and, at the same time, caused the ring itself to more closely grasp the shell. In breech loading guns there is a band of soft metal about the projectile which makes it a little larger in diameter than the caliber of the gun; the powder gases force this band to take the grooves, and, by this means, the twist is imparted to the projectile.

Projectiles against Armor.—It is worthy of note that with the improvement of the steel projectile, the steel face of compound armor became more and more hardened, and carbon was added until there was 40 per cent. more used in 1888 than had formerly been thought necessary. When the Holtzer projectiles were tried in England, in March, 1887, the excellent results obtained were claimed to be largely due to the fact that the plate was of inferior quality, and a new trial came off in October of the same year, the target being the best 16-in. compound plate that could be made. It was in fact the second half of the plate that had so successfully withstood the attacks of Firminy projectiles in the early part of the year. The projectile weighed 714 lbs.; the plate was broken into two parts, and cracks were developed all over its surface. When removed from the target-backing the shell was intact, and so little deformed that, apparently, it could have been fired again. A Palliser shot fired under similar conditions to a Holtzer was shattered into fragments.

A lot of 300 Holtzer 6-in. shell were fired at Shoeburyness against a Brown 9-in. compound plate. The first shell perforated the plate without further injury than a slight cracking in the head; the second failed to get through, and, breaking off at the front band, rebounded 12 yards. As the requirements were that test shell should pass through a 9-in. compound plate practically undeformed, the lot was rejected. A former lot had, however, passed the test, as did some Holtzer steel projectiles fired against Creusot plates 5.5 in. thick.

Early in 1888, projectiles 13.5 in. in caliber, weighing 1,250 lbs., were fired against Cammell plates 18 in. thick. The first shot against this plate was a Firminy shell and was completely broken up. A St. Chamond projectile was fired against a Brown plate during the same series of trials, and was also broken up. Firing against a Brown 9-in. plate was tried later in the same year, Firminy 6-in. shells being used. The two test shells passed through the plate and were but slightly cracked and deformed. An armor-piercing trial with St. Chamond 12-in. projectiles took place in Russia; the plate was of the Wilson patent, but made in Russia. Although the plate was fractured, the shot did not get through; the point barely pierced the plate, leaving the base projecting from the other side, the surface of the projectile being badly cracked in all directions.

In 1890 there were two important trials of projectiles *versus* armor: the first in this country at Annapolis, and the second at Ochta, in Russia. At the former the energy of the 6-in. Holtzer armor-piercing projectile was a little more than sufficient to just perforate the steel plate. The other two plates used were a nickel-steel and a compound armor. There were twelve 6-in. 100-lb. projectiles fired, four at each plate, with the following results: The first shot fired at the steel plate was not materially injured, its base projected 6·5 in. from the plate; the second penetrated but rebounded, and was found to be shortened 10 of

an inch; the third did the same, and was shortened .14 of an inch; the fourth acted in the same manner, but was broken up. The compound plate let the first three through without injury to the projectiles, but the fourth broke after perforation. The body of the first shell fired at the nickel-steel remained in, but the rear end rebounded; the second remained intact in the plate; the third the same, excepting that the base projected 4·5 in.; while the fourth broke, leaving its head in the plate, the rear portion rebounded. A fifth shot was fired at each plate, the projectile being an 8-in. Firth-Firminy. The one fired at the steel plate penetrated, rebounded, and broke in three pieces. The nickel-steel let the projectile enter, but broke it 5·25 in. from the face of the plate, part of the head remaining in the hole. The shell fired at the compound plate was recovered entire, but was shortened 0·24 in.; much of the plate was damaged, the hardened front portion was scaled off in a number of large and small pieces.

In the Ochta trials the first two projectiles used were of poor quality, but the last three were excellent, and a comparison with their performance against a Vicker's plate and the Schneider steel plate at Annapolis shows that in the former the points of the three projectiles penetrated 7,11, and 4 in. beyond the back of the plate, while in the latter the penetrations of the four 6-in. projectiles beyond the back of the plate were respectively 2·75, 2·4, 2·0, and 2·4 in. Against the nickel-steel 10-in. plate the Holtzer 6-in. shot first fired penetrated 9 in., and rebounded, broken in two; the second penetrated 8¾ in., and rebounded, broken in three pieces; the third went in 11½ in., and rebounded unbroken; while the fourth entered 9¾ in. and broke in two. The first at the compound plate entered 13·2 in. and remained entire in the hole; the second did likewise; the third perforated plate and backing, and was found unbroken 817 yards to the rear; and the fourth was intact 933 yards to the rear. The two nickel-steel plates differed somewhat in constitution, containing unequal proportions of nickel, which will account for the different effect upon the projectiles.

The most important struggle between armor and projectiles in this country took place in 1891 at the new naval proving grounds at Indian Head, on the Potomac River. In this the plates were of domestic manufacture, and a portion of the projectiles used were also made in this country. Six plates were used, four 6-in. and one 8-in. projectile being fired at each plate under circumstances similar to the trials already referred to. The general result to the projectiles was in the main like that of the trials at Annapolis, and a positive proof was given of our ability to improve on original designs and to obtain in this country all the armor-piercing shell that we need.

The Carpenter projectiles are made of chrome-steel, after the Firminy process; that is, all of the patents covering that process were purchased for use in this country; but something better was expected, as the conditions of the armor were changed first from steel to nickel-steel, and then from the ordinary methods of hardening to the adoption of the Harvey system. Consequently experiments were started in hardening the head of armor-piercing shell, and departures were as a natural sequence found necessary. The tempering does not run to the same extreme throughout the shell, as the thinner walls about the powder chamber would not stand the treatment and maintain the desired degree of efficiency; the head, and as far down as the chamber will admit, are treated, and the projectiles have thus far answered every demand. They are delivered in lots of 100 each, two out of every lot being taken as samples.

Common steel shell are being made by two different processes, one in which they are pressed into shape by means of dies, and the other by the use of electric welding. In the former the shell are made from a cylindrical billet of steel, which is heated and put through a series of dies and presses, which hollow it, draw the sides of this cup-shaped hollow to form the powder chamber, point it, leaving a hole at the apex for the insertion of the fuze; shape the powder chamber inside; and when the operation is finished nothing remains but to cut the screw-thread for the receipt of the fuze. These projectiles can be turned out in any quantities desired, and at a far less cost than the armor-piercing type which are turned by machinery. The method above described has been in use abroad for some years, but the machinery as adopted in this country has undergone considerable change from the original.

The Wheeler-Sterling Shell.—A new armor-piercing steel shell, named the Wheeler-Sterling, and hardened by a process that is at present kept a secret, has recently given such excellent results that a number of the projectiles are being made for naval use. A 6-in. shell, weighing 100 lbs., was recently fired through a high-carbon steel armor plate 11½ in. thick. The shortening after this severe ordeal was but 0·38 in., and the enlargement 0·23 in. The point was not at all distorted, nor was there a scratch to mar the surface from point to base. This is the first American armor-piercing shell made after an American patent and process, and the result is quite remarkable.

Rapid-fire Projectiles.—The projectiles for rapid-fire artillery, besides being made by the well-known methods of making shell and shrapnel, are now made also by the electric welding process. Iron tubing is cut in suitable lengths, and to this are welded steel heads and bases. Experiments on the proving ground with projectiles of this type have proved them to be well adapted to the purpose; and it is now thought that the larger-calibered shell for ordinary service can be made by the same method. The rapidity and comparative cheapness with which shells made in this way can be turned out recommend the process, which, at present, bids fair to displace all other methods of manufacturing ordinary shell and shrapnel for quick-fire guns. (See WELDING, ELECTRIC.)

Hotchkiss Projectiles.—The Hotchkiss guns are furnished with ammunition made especially for their guns, and it is of three kinds: Cast-iron shell, steel shell, and case-shot. The two former have the same general appearance, and are of the cylindrical ogival type;

the point of the steel shell is sharply pointed, and the fuze is inserted in the base ; the cast-iron shell has a percussion fuze fitted to the front end, which is truncated to form a seat. A number of grooves are cut around the body of the projectile, and over these is forced a sheet-brass belt. When the gun is fired this belt is forced into the grooves, and gives the rifling motion to the projectile. Both classes of shell are shaped with great care and turned true ; those of steel are tempered. The case-shot consists of a shell of thin brass filled with lead balls, the intervening spaces being filled with sawdust.

Calibers and Projectiles, U. S. Guns.

Nature of Gun.	Caliber.	Weight.	Length.	Weight of charge.	Weight of projectile.	Muzzle velocity.	Muzzle energy.	Thickness of steel which shell will penetrate at muzzle.
Breech-loading Rifles.	In.	Lbs.	Ft.	Lbs.	Lbs.	Ft. sec.	Ft. tons.	In.
4-in. Mark I................	4	3,380	13·7	12–14	33	2,000	915	7·18
4-in. Rapid Fire...	4	3,400	13·7	12–14	33	"	"	"
5-in. Mark I...	5	6,190	13·5	26–29	60	"	1,660	8·67
5-in. Rapid Fire........ ...	5	7,000	17·4	28–30	50	2,250	1,754	9·00
6-in. Mark I	6	10,775	15·8	50	100	2,000	2,773	10·27
6-in. Mark II...	6	10,900	16·1	45–48	"	"	"	"
6 in. Mark III., 30 cals	6	10,800	16·3	44–47	"	"	"	"
6 in. Mark III., 35 "	6	11,554	18·8	"	"	2,080	2,990	10·86
6-in. Mark III., 40 "	6	13,370	21·3	"	"	2,150	3,204	11·38
8-in. Mark I................	8	27,600	21·5	105	250	2,000	6,932	14·51
8-in. Mark I................	8	28,800	"	115	"	"	"	"
8-in. Mark II................	8	29,100	"	"	"	"	"	"
8-in. Mark III., 35 cals....	8	29,400	25·4	"	"	"	7,498	15·61
8-in. Mark III., 40 "	8	34,000	28·7	"	"	2,150	8,011	16·10
10-in. Mark I., 30 cals. ...	10	57,500	27·4	225–224	500	2,000	13,864	18·75
10-in. Mark I., 35 "	10	{ 60,660 63,100 }	30·5	"	"	2,080	14,996	19·83
10-in. Mark II., 30 "	10	56,400	27·4	"	"	2,000	13,864	18·75
10-in. Mark II., 35 "	10	61,900	31·2	"	"	2,100	15,285	20·10
12-in. Mark I................	12	101,300	36·8	425	850	"	25,985	24·16
13-in. Mark I................	13	135,500	40·0	550	1100	"	33,627	29·66

High-explosive Projectiles.—In addition to the dynamite gun projectiles (see TORPEDOES) there have been numerous experiments made to devise a method for the safe projection of high explosives. In 1887 experiments were made at Sandy Hook with steel shell of service pattern, but provided with a large base opening for convenience of loading ; the weight of each, including the bursting charge of 2·3 lbs. of dynamite, was about 122 lbs. The weight of powder charge was 23 lbs. The Graydon method of charging shell consists in subdividing the bursting charge into small pellets, each enclosed in a separate envelope, which is treated with paraffine. The interior of the shell is carefully lined with asbestos. The fuze is composed of a funnel-shaped vessel of sheet metal, having its large end in contact with or close to the front wall of the projectile, while its rear end sits over the fuze proper, a cylindrical tube filled with powder and armed in front with a percussion cap. Seven rounds were fired at a section of a wrought-iron turret, 14 in. in thickness, and made up of two 7-in. plates ; each of these was divided horizontally into two sections, so disposed as to break joints. The shell were successfully fired from the gun, and serious damage was inflicted on the target; especially was this the case in the third round, when penetration and disruptive effect on the target were combined. This system has since undergone a series of trials in England and France, where, on account of there being neither special gun nor special projectile required, it has attracted considerable attention.

The Smolianinoff shell, charged with high explosive, was fired from a 100-pounder Parrott rifle at the Sandy Hook proving grounds in November, 1887. The weight of empty shell in the first two rounds was 89 lbs., and the weight of explosive was 4·6 lbs.; in the last round the shell weighed 82 lbs., the explosive 4·1 lbs. The explosive consists of 80 per cent. of nitro-glycerine, and it is claimed that it is insensible to shock, either in the gun or against a target of earth or stone, and that a detonating fuze is required to explode it. The weakness of the cast-iron shell used in the three rounds that were fired, and also the shape of the head, which was adapted to a nose-fuze, precluded any possibility of penetrating the target, which was like the one above described. The firing was successful in the respect that no damage was done to the gun.

The Snyder explosive consisted of 94 per cent. nitro-glycerine, and 6 per cent. of a compound of collodion, gun-cotton, camphor, and ether ; it is exploded by mere percussion against any hard and solid body, and it seems to be wholly within the power of the manipulator to prevent premature explosions. The gun employed in the experiments, that took place under direction of the Turkish war department, was a 6-in. rifled field-piece. The target, erected at a distance of 220 yards, was composed of twelve 1-in. steel plates, welded

together, and backed by oak beams; the charge of explosive was 10 lbs. Ten shots were fired without accident of any kind, and without damage to the gun, the target being completely destroyed by one of the shots.

In 1883, in Germany, a patent was obtained for the construction of a shell to be charged with high explosive, but nothing in the way of experiments was done with the projectile, which was of special construction, and in 1885 a patent was secured for a new process of loading, which could be applied to shell of service pattern. The wet gun-cotton used in this is in the form of prismatic grains, made by cutting up the ordinary compressed disks, and to the charge of wet are added about 200 grams of dry cotton. Space being reserved for the fuze and detonator, melted paraffine is poured over the charge, filling in all its interstices, and, as it cools, forms the charge into a solid mass. Over 200 shell have been fired from an 8.8-cmt. gun without accident, and with complete explosion. Charges of 16 kilograms have been successfully fired from the 15-cmt., and the experiments have since extended to the 28-cmt. mortar. In March, 1888, a 98-kilogram projectile, loaded with gun-cotton and 22 kilograms of powder, was fired from a 21-cmt. Krupp gun. The shell perforated a 12-cmt. compound plate, its 60 cmts. of oak backing, and only burst when it entered an earthen wall at the rear of the target. (See ARMOR; GUN, PNEUMATIC; ORDNANCE, and TORPEDOES.)

Projectiles, Dynamite: see Torpedo.

Propellor: see Engines, Marine.

Pug Mill: see Clay-working Machinery.

PULVERIZERS AND HARROWS. The "pulverizers" constitute connecting-links between the plow and the harrow, and are, indeed, loosely termed harrows; but the action of those with obliquely revolving disks cuts and turns the earth after the manner of the ordinary plow, rather than by raking and scratching it like the harrow proper. The tendency of the revolving-disk "harrow" to encroach on the province of the common breast plow is illustrated by Clark's cutaway disk machine, Fig. 1, which cuts a furrow 40 in. wide and may be run as much as 7 in. deep. It lifts the soil, inverts it, and effectually aërates it. Each of the revolving members is a 24-in. notched disk, dished, and sharpened at the edges, and behind each is suspended a spring-steel moldboard to turn each furrow or cut. Stationary cleaning-knives are added, to scrape any adhering dirt from the disks. A sharp revolving disk land-side precedes each of the notched disks which act as shares. The land-sides do also the work of coulters. A long beam is used, supported at its front end by a 16-in. caster. The plow-heads are supported and gauged by two 24-in. carrier-wheels on a hinged axle governed by a hand lever at the right. The depth of cut of the land-sides is governed by a hand lever on the beam. The lever at the left adjusts the moldboards. The original disk-harrow was furnished simply with a gang of revolving circular dished disks.

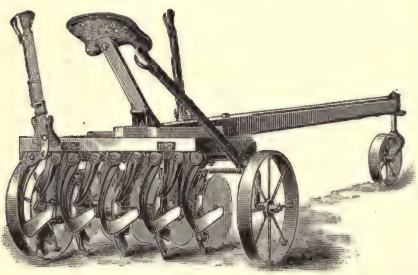


FIG. 1.—Cutaway disk pulverizer.

The change of the form of the disks, in the implement under consideration, by cutting away portions at regular intervals so as to leave merely the five or six spade-like blades on each rolling member, has given this class of machine a new impulse of usefulness. Thus made, the blades "scour" better than before in all soils, but are comparatively free from the fault of trailing the soil into ridges, and leaving a dead-furrow or gulley at the center line of travel or the two outer edges, according as the disks are set on an inward or outward gather. The implement is suitable for stubble-plowing and all free-working soils, also hard adobe and clay, but not for stiff sod or very sticky soils. It does not need the heavy weighting required by the solid disk machines, especially on sod lands, fields that have been plowed some months previously, or corn, wheat, or other grain-stubble lands. Four horses are advantageously used. Where this class of machine is used on such land the tilth is better than that of the ordinary plow, and consumes far less time. The cutting edge of a round disk of the customary size is some 50 in., and some 50 ft. of cutting edge must therefore be pressed into the earth at each revolution; while the "cutaway" penetrates the earth with only some 22 ft. of cutting edge, and, therefore, with considerably greater ease. In working say 4 in. deep, each circular disk must have an incisory bearing of some 15 in. per revolution, making 15 ft. of incisory bearing for a twelve-disk machine; but the "cutaway" machine, with the same number of disks and depth of work, has less than 8 ft. of incisory bearing; this diminishes the draft, and yet the disks, by their troweling action, chop the soil into finer fragments. In the Clark cutaway pulverizer, six shovel-blades enter the earth at each revolution of each member, making nearly a quarter turn to stir the earth laterally four inches, crumbling it quite finely. Clark's disk is shown separately in Fig. 2.

FIG. 2.—Cutaway disk.

All harrows of the rotating-disk class are subject to a considerable amount of side pressure on each disk, which accumulates at the rearward hanger, causing a severe friction there. For this hanger, the Keystone Manufacturing Co., of Sterling, Ill., make for their machine

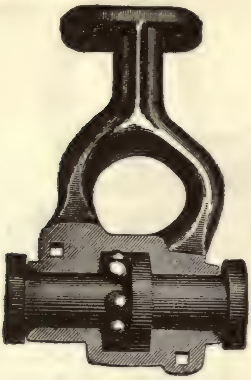


FIG. 3.—Ball bearing.

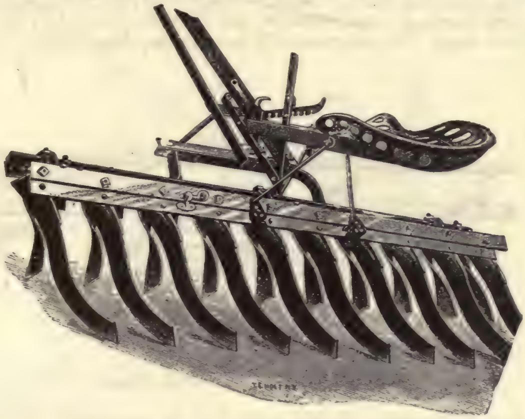


FIG. 4.—The Acme harrow.

of the same class the ball bearing exhibited in Fig. 3 (shown with side-plate removed), which diminishes the wear and eases the draft.

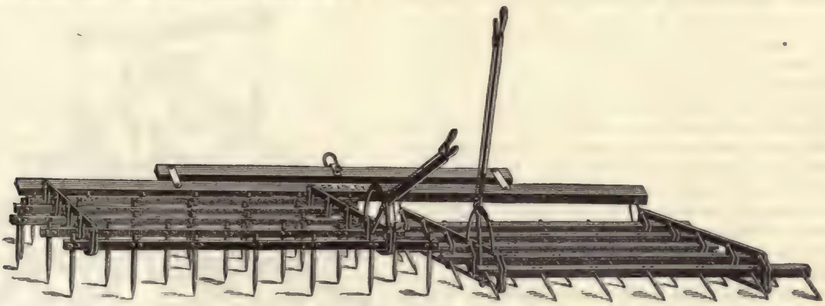


FIG. 5.—Bradley's harrow.

The "Acme" harrow (Fig. 4.) includes the functions of clod-crushing and pulverizing plowed ground. The front cutters are deflected to one side, and the rear cutters to the other,

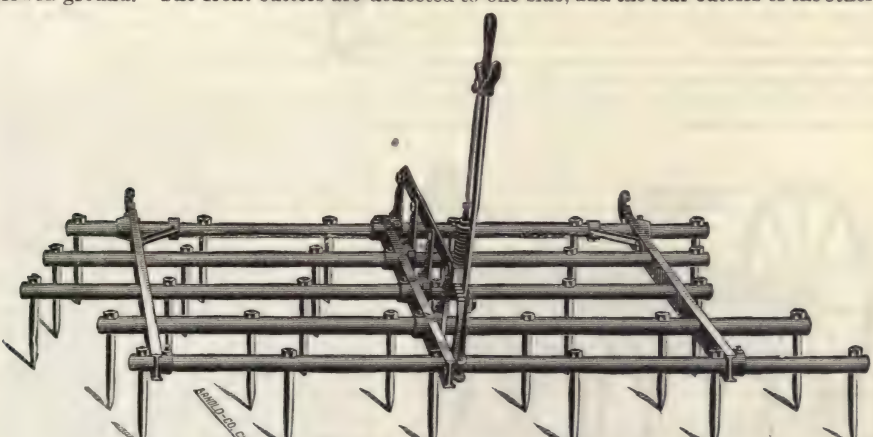


FIG. 6.—Gale's harrow.

to neutralize tendency to ridge the soil. The angle of the cutters is adjustable, and they are reversible, doubling their service. Bradley's steel lever-harrow (Fig. 5) will serve to illustrate the improvement by which the entire harrow-frame, connected throughout by a series of pivoted rods, is manipulated by levers to incline the pitch of the teeth backward, thus chang-

ing the implement from a stirring to a smoothing harrow, or causing the removal of any gathered trash from the teeth.

Another form of the same class of lever-harrows is shown in Fig. 6, and is strongly made of pipe passing loosely through transverse flat girts, each piece of pipe being connected by an arm pivoted to a horizontal bar, in turn pivoted to the hand lever for adjusting the pitch of the teeth. A lever-harrow by the Ray Implement Co., shown in Fig. 7, has a bearing

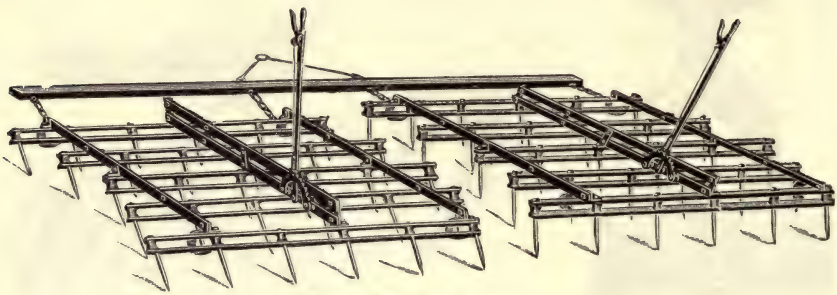


Fig. 7.—The Ray harrow.

shoe at the corner of each section. In transporting this harrow, when it is not desired to operate it, the teeth are thrown back horizontally by the lever, and the corner shoes take the ground as runners. The H. P. Deuscher Co. makes a harrow with sledge runners so arranged as to carry the implement folded and reversed when transporting it not in use. The class of harrows represented by the Kalamazoo spring-tooth harrow (Fig. 8) is not only adapted by the yielding teeth to land that is obstructed by earth-fast stones and other objects, but, owing to the vibratory action of the helix spring-teeth, pulverizes the soil thoroughly, shakes it up and leaves the dirt in a loose condition, shaking out weeds and grass upon the surface, leaving them exposed to the sun to wilt and die. In operation the flattened frame pieces hold down the sods and clods, while the teeth cut deeply through instead of rolling them up. Each tooth has a bead punched up near the heel, which matches a cast-iron socket on the harrow frame. The socket is made with a rib which matches a slot in the harrow frame, and has side flanges to prevent the tooth from swinging to either side. The tooth is held to the socket by a steel clip. The same class of harrow is sometimes iron-plated on the bottom surface of the frame to promote durability, and sometimes made with the frame entirely of iron or steel, corrugated longitudinally to render it rigid. The teeth are also sometimes made with the heel prolonged and continuing the normal curve, so that as the points wear away the depth of cut can be maintained, and the service of the teeth increased by changing the point of attachment nearer to the extremity of the heel as occasion may require. Fig. 9 is the Hoosier pressure-harrow, with a hand lever attached to a rock-shaft having a series of arms controlling the depth of cut by means of connecting rods. The teeth are fitted with springs at the heels, permitting them to yield to avoid breakage. By removing or folding up the middle tooth, the harrow is used as a corn cultivator, the dragbar support being high enough to pass over the growing corn. Fig. 10 exhibits the Hench & Dromgold method of securing the flat class of spring-tooth on a steel-frame harrow. The tooth is riveted to a malleable iron hub with ratcheted sides, and a bolt passes through the frame pieces of the harrow, and two circular plates with crown ratchets to engage the hub ratchets As the tooth wears away and shortens at the point, the hubs may be correspondingly rotated by

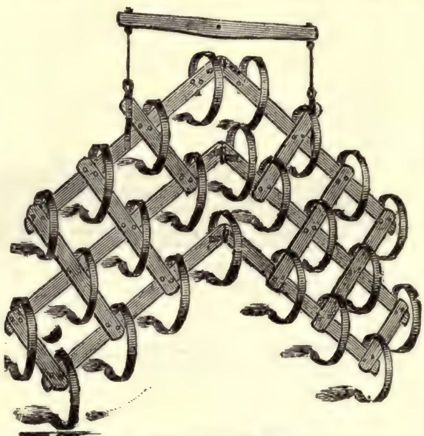


Fig. 8.—Spring-tooth harrow.

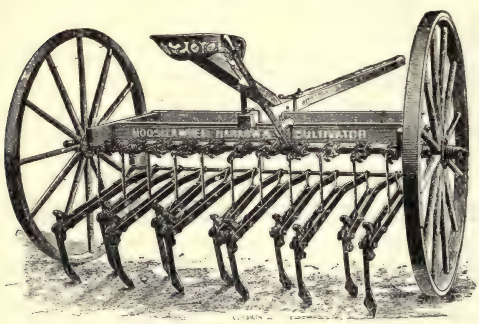


Fig. 9.—The Hoosier pressure-harrow.

loosening the bolt and then retightening it, to maintain the normal depth of cut, so as greatly to increase the service of the teeth before exhausting all their available spring action.

The grubber (Fig. 11) is distinguished by a pair of side carrier-wheels and a lead-wheel.

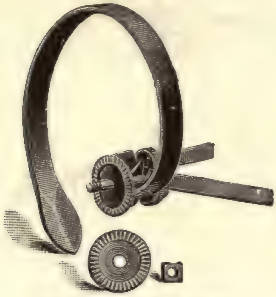


FIG. 10.—Spring tooth.

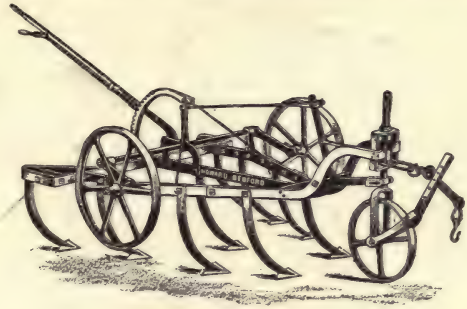


FIG. 11.—Grubber.

These wheels merely limit the depth of cut by the teeth as long as the hand lever is latched back; but when the lever is released, the advance of the teeth lifts the teeth from the ground, and loads the machine bodily upon the wheels.

PUMPS, RECIPROCATING. *The Worthington High duty Pump.*—One of the most important recent inventions in pumping machinery is that of the high-duty attachment to the Worthington duplex pumping-engine, by which engines of the direct-acting, reciprocating type, without fly-wheels, may be caused to store up energy during the first part of the stroke, to be given out toward the end of the stroke, and so utilize the advantages of expansion in the steam-cylinders to the highest degree. This improvement is thus described by Mr. J. T. Holloway, in a paper presented to the American Society of Mechanical Engineers (Trans., vol. xi.). Fig. 1 shows a sectional elevation of a compound direct-acting steam-pump, having attached to it what has been called the high-duty attachment. To ordinary compound direct-acting steam-pumps, as usually built, there is attached a plunger-rod which projects through the outer end of the pump chamber, and around which there is the usual stuffing-box for packing the same. On the end of this plunger-rod is fastened a cross-head, which moves in guides bolted on the outer end of the pump. On this cross-head and opposite to each other are semi-circular recesses. On the guide plates are cast two journal boxes, one above and one below the plunger-rod, both equidistant from it, and at a point equal to the half stroke of the cross-head. In these journal boxes are hung two short cylinders on trunnions, which permit the cylinders to swing backward and forward in unison with the plunger-rod. Within these swinging cylinders are plungers, or rams, which pass through a stuffing-box on the end of the cylinder, and on their outer ends they have a rounded projection which fits in the semi-circular recesses in the cross-head; and, consequently, as the cross-head moves back and forward, it carries with it these two plungers, which in turn tilt the cylinders back and forward on their trunnions. These swinging cylinders are called "compensating cylinders," and they are filled with the fluid being pumped.

The pressure on the plungers within the compensating cylinders is produced by connecting these cylinders through their hollow trunnions with an accumulator, the ram of which is free to move up and down as the plungers of the compensating cylinders move in and out. The accumulator used is of the differential type; it has below a small cylinder filled with water or oil, within which its plunger moves, while above it has a larger cylinder filled with air, and within which there is a piston-head which fits closely to the cylinder, and is at the same time attached to the top of the plunger in the lower cylinder.

By this arrangement it will be seen that the pressure per square inch on the plunger or ram of the accumulator will be the pressure per square inch on the piston-head in the upper cylinder multiplied by the difference between the area of the piston-head and the lower plunger. This difference of areas is a matter of calculation, based upon the particular service for which the pump is constructed. The pressure in the air-cylinder is controlled by the pressure in the main delivery pipe of the pump, as it is connected to that pipe. This connection with the main has another very important use, as the power exerted by the compensating cylinders is a very considerable part of the power used in driving the pump plunger at the latter part of its stroke and it will be seen that if for any cause, either by the breaking of the main or otherwise, the load is entirely thrown off the pump, the plunger cannot make a disastrous plunge forward, for the reason that the steam in the steam-cylinder is, by reason of its expansion, too low in pressure to drive it, while the fall of pressure in the main has robbed the accumulating cylinders of their power.

Test of a Worthington High-duty Engine.—Fig. 2 shows a set of three duplex compound direct-acting pumping-engines, built by Henry R. Worthington for the Artesian Water Co., Memphis, Tenn. The engines, each of which is of 10,000,000 gallons capacity, and works against a head of 250 ft., are essentially the same in principle as the horizontal engines built by the same firm, but are modified to suit the different conditions. The high-pressure cylinders are placed on top, and are 30 in. diameter, the low-pressure cylinders

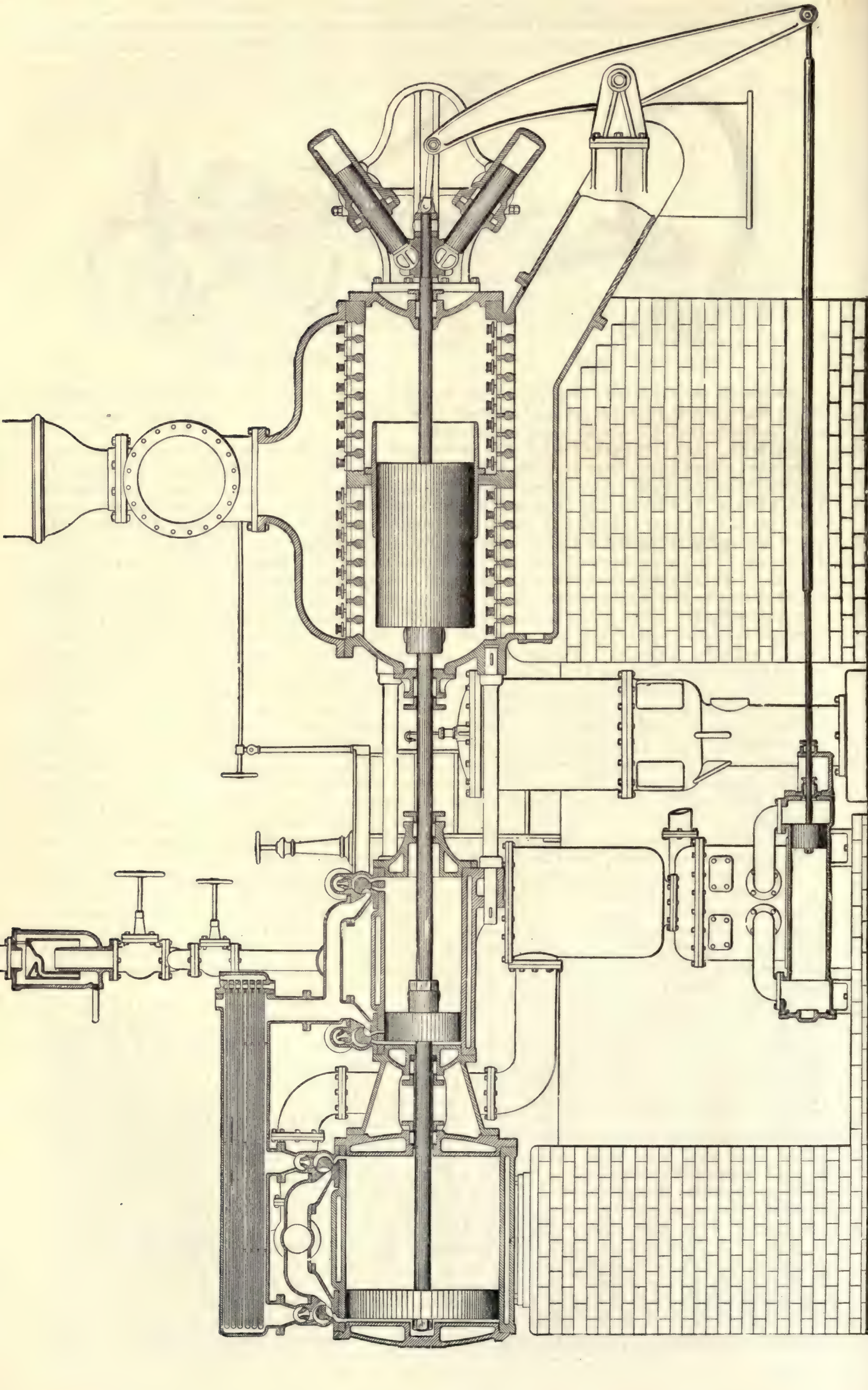
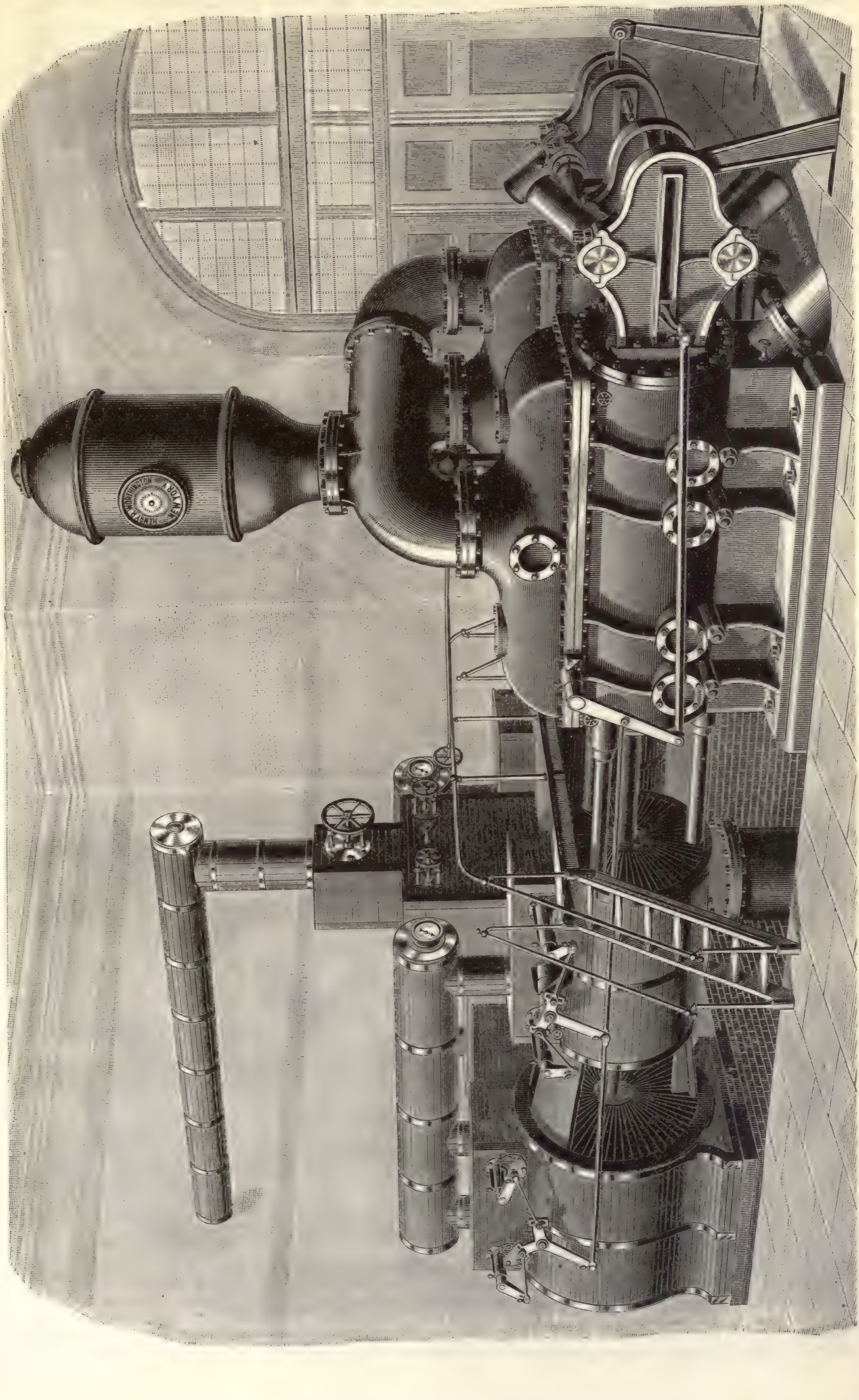


FIG. 1.—The Worthington high-duty pumping engine. (Sectional view.)



Worthington high-duty pumping engine.

being directly under them, and 60 in. diameter. The pump plungers are 27 in. diameter, and the stroke is 48 in. The valves are of the Corliss type, with a cut-off valve placed over

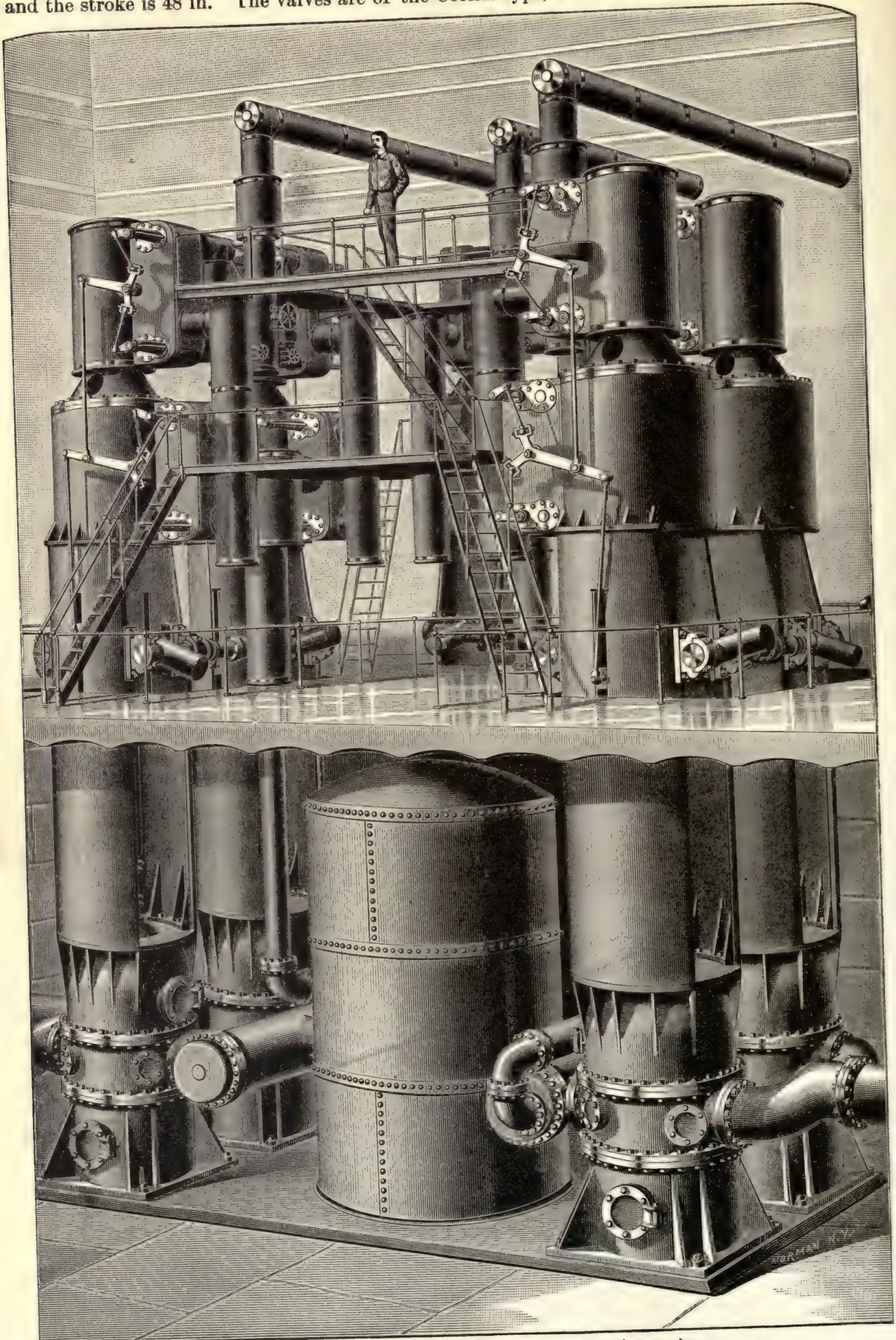


FIG. 2.—Worthington compound direct-acting pumping-engines.

them, but are not, of course, worked by the Corliss valve motion, since the point of cut-off is fixed. The compensating cylinders are, on these engines, placed on the frame between the

steam and water ends, their plungers being connected directly to the main piston-rods. Below the compensating cylinders, and inside the frames, is a balancing device on each piston-rod, which exactly balances the weight of the reciprocating parts. This consists simply of a cylinder through which the piston-rod passes, and is provided with a piston to fit the cylinder, stuffing-boxes being provided at each end above and below. Below this piston is water, which, as the piston descends, is forced out of the cylinder through a pipe against a pressure of air, this air pressure forcing the water back into the cylinder again, and lifting the weight of the reciprocating parts during the up-stroke. The pressure of air for this is restored to the proper amount by means of the auxiliary compressor, when it becomes reduced through leakage.

Engine Test.—Cylinder diameters: high-pressure, 30 in.; low-pressure, 60 in.; water, 27 in. Length of stroke: nominal, 4 ft.; average during trial, 4·1625 ft. Average steam pressure at engine, 105·16 lbs.; average pressure in force main, 95·67 lbs.; average vacuum in suction main, 2·38 lbs.; pressure equivalent to difference between the two gauges, 26·13 lbs.; net load on plungers, per sq. in., 124·18 lbs.; mean effective pressure: high-pressure cylinder, 48·82 lbs.; low-pressure cylinder, 14·666 lbs. Average piston speed per minute, 133·3 ft.; net work done in the 24-hour test, 26,779,100,000 ft. lbs.; duty per 1,000 lbs. feed water, 117,325,000 ft. lbs.; capacity in 24 hours, as calculated from plunger displacement, 11,202,000 gallons. Average indicated horse-power developed by steam cylinders, 605·88 horse-power; horse-power calculated from work done, 563·5 horse-power; efficiency of engine, 93 per cent.; dry coal actually burned per indicated horse-power per hour, 1·74 lbs.; pounds of water evaporated from feed at 153·26° F. to steam at 110·06 lbs., per indicated horse-power per hour, 15·70 lbs.

The Gaskill Pumping-engine, made by the Holly Manufacturing Co., Lockport, N. Y., is shown in Fig. 3.

On a heavy iron bed-plate are mounted two pumps, and in direct line therewith two low-pressure steam-cylinders, with the piston-rods of the low-pressure steam-cylinders connected to the piston-rods of the pumps. Between the pumps and steam-cylinders are placed two beam supports, which carry the beam shafts and beams, the lower end of the latter being connected to the cross-heads of the low-pressure cylinders by means of links. On the top of the pumps are placed the main shaft bearings, which support the shaft, fly-wheel, and cranks, the latter being keyed to the shaft at right angles to each other. On the top of the low-pressure steam-cylinders are mounted the two high-pressure steam-cylinders, with their centers in the same horizontal plane as the center of the main crank shafts. Two cross-heads for the high-pressure steam-cylinders are connected by means of links to the upper ends of the beams, and the beams are in turn connected by means of connecting-rods to the crank-pins. From the high-pressure steam-cylinders heavy cast-iron girders extend to the pillow blocks. On the inner end of each of the beam centers an arm is keyed, from which the air-pumps are driven. The valves of the steam-cylinders are operated by means of eccentrics keyed on a shaft, which is at right angles with and driven by the main shaft through small bevel gears. The admission valves to the high-pressure steam-cylinders are of the double-beat puppet pattern, so arranged as to open at the proper time and to close at any desired point of the stroke. The exhaust valves from the high-pressure cylinders serve also as admission valves to the low-pressure steam-cylinders, and are of the ordinary slide-valve type, and are set so as to remain open somewhat less time than is required to make a complete stroke. The exhaust valves from the low-pressure cylinders are also plain slide valves, operating in the same manner as the high-pressure exhaust valves. The plungers are arranged to work through glands in the centers of the pumps, and are accessible from the covers at the ends of the pump cylinders. The pump valves are placed on horizontal plates below and above the line of the plunger travel. The glands above mentioned divide the valves of one end of the pump from those of the other end, at the center of the valve plates.

Test of a Gaskill Pumping-engine.—The following is condensed from a report by Prof. D. M. Greene, of the Rensselaer Polytechnic Institute, of a test made by him of the Gaskill Duplex Compound Engine, at Saratoga Springs, in 1889:

The principal dimensions of the engine and pumps are as follows: Diameter of high-pressure cylinders, 27 in. Diameter of low-pressure cylinders, 54 in. Diameter of pump plungers, 25 in. Stroke of steam-pistons and pump plungers, 40 in. Diameter of high-pressure piston-rods (steel), 3·5 in. Diameter of low piston-rods (2) (steel), 4·5 in. Diameter of pump rods, 5 in. Diameter of crank shaft (fagoted iron), 12·5 in. Diameter of hub of crank, 22·5 in. Depth of crank, 11 in. Diameter of crank-pins (steel), 7·5 in. Length of crank-pins (steel), 9 in. Length of beam between centers, 63 in. Length of upper beam pin, 14 in. Diameter of upper beam pin, 6 in. Length of lower beam pin, 6 in. Diameter of lower beam pin, 6 in. Diameter of fly-wheel, 16 ft. Depth of rim of fly-wheel, 16 in. Width of face of fly-wheel, 14 in. Weight of fly-wheel, about 28,000 lbs.

The clearance space in all of the cylinders is small, and is taken at 2·7 per cent. and 3 per cent. in the high- and low-pressure cylinders, respectively. The pumps, which are double-acting, are each fitted with 700 "Troy" valves, each of about $1\frac{1}{2}$ in. diameter and $\frac{3}{8}$ in. lift. At each end of each pump, therefore, there are 175 induction and 175 eduction valves, giving an aggregate valve opening for the reception and discharge of the water equal to more than 0·6 of the effective area of the plunger. The loss of head due to the passage of the water through the pumps is probably not greater than 0·25 of a foot.

Steam is furnished to this engine by two horizontal cylindrical boilers, of the following proportions: Total area of grate surface, 66 sq. ft. Total heating surface, (about) 2,866

sq. ft. Total area of cross-section of tubes, 7·18 sq. ft. Total area of chimney flue, 8·33 sq. ft. Ratio of heating surface to grate surface, 43.42. Ratio of grate surface to area through tubes, 9.19. Ratio of grate surface to area of chimney flue, 7·92.

The following average values are obtained from the records of the test: Mean steam

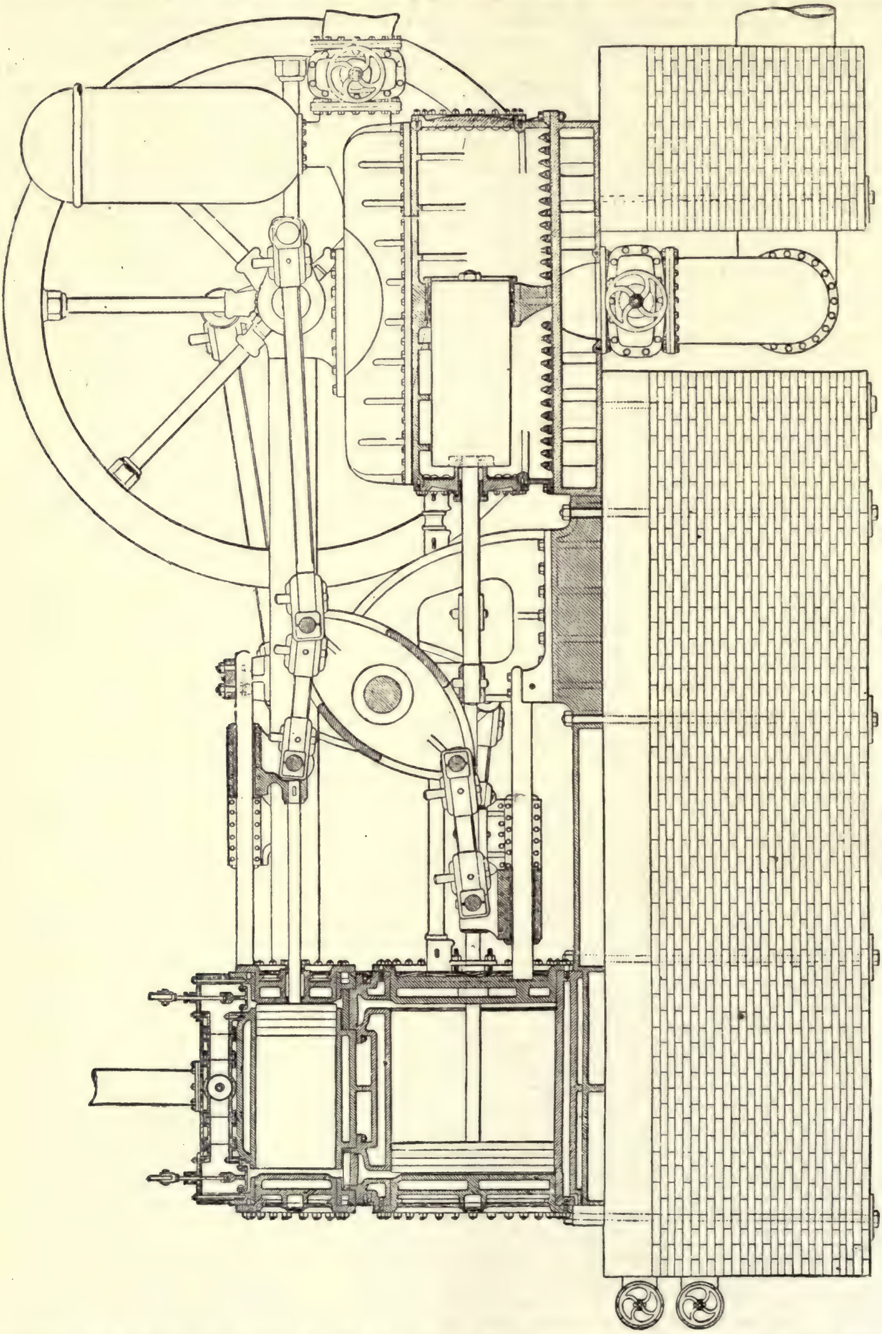


Fig. 3.—Sectional elevation, Gaskill horizontal pumping-engine.

pressure in boilers, per gauge, 81·05 lbs. Mean steam pressure at engine, per gauge, 78·01 lbs. Mean steam pressure in jackets, per gauge, 70·075 lbs. Mean water pressure. per gauge, 99·565 lbs. Total mean pressure on pumps, corrected, 103·735 lbs. Mean vacuum, per gauge on condenser, 28·9 in. Mean vacuum, per gauge on engine, 27·87 in. Mean temperature of feed water, 203·55° F. Mean volume of water, at 51°, passing the meter per

hour, 88·014 cu. ft. Mean revolutions of engine, per minute, 17·04. Mean effective area of plunger, 481·0575 sq. in. Mean rate of coal consumption, per hour, 600 lbs. Mean rate of consumption per hour per square foot of grate, 9·091 lbs. Mean rate of evaporation in boilers, per minute, 96·135 lbs.

Substituting in the duty formula the values found, for the duty, 117,936,698 ft. lbs., on the basis of the assumed evaporation of 10 lbs. of water per pound of coal, this result exceeds the guaranteed duty, 105,000,000, by 12·32 per cent., or by nearly one-eighth. The duty, based upon the actual coal consumption, is 113,378,479 ft. lbs. This result is 7·98 per cent. greater than the duty guaranteed. The capacity of the pumps of the new Saratoga engine is 333·2 U. S. gallons per revolution, and the rate at which water was pumped during the period of the test of eighteen hours was, therefore, 8,175,928 gallons in 24 hours, at a piston speed of 113·6 ft. per minute. This rate is something more than 2 per cent. greater than required by the contract, while the pumps were operated against a pressure 3·73 per cent. greater than was required. The quantity of water actually pumped during 24 hours, against a pressure of 103·575 lbs., and at a piston speed of 115 ft. per minute, was 8,277,354 U. S. gallons; exceeding the contract capacity by 3·47 per cent. against a pressure 3·57 per cent. greater than was required by the terms of the contract.

The following facts have been deduced from the steam cards: Clearance of high-pressure cylinders equivalent to fraction of stroke, 0·027. Clearance, low-pressure cylinders, fraction of stroke, 0·030. Mean pressure at end of stroke, both low-pressure cylinders, 7·7565. Mean expansions in high-pressure cylinders, 2·933. Mean expansions in low-pressure cylinders, 4·207. Mean expansion, total, by pressures, 12·349 times. Pounds of steam entered cylinders, per minute, 87·348. Of this, there is accounted for at cut-off, 73·95 per cent.; at the end of stroke in the high-pressure cylinders, 78·82 per cent., and at the end of the stroke in the low-pressure cylinders, 89·08 per cent.

Thus it appears that at the cut-off there was, in the high-pressure cylinders, water constituting 26·05 per cent. of the steam and water which entered the cylinders. At the end of the stroke in the high-pressure cylinders, there appears to have been water constituting 21·18 per cent. of the water and steam originally entering the cylinders, and at the end of the stroke in the low-pressure cylinders there was water constituting 10·92 per cent. of the steam and water which originally entered the cylinders.

The Corliss Pumping-engine at Pawtucket, R. I.—This engine, built in 1878, was described in Vol. II. of this work. Numerous tests of its working have shown that it has uniformly given a remarkably high record of economy. It is a horizontal cross compound engine, steam-cylinders, 15 and 30½ in. bore; water cylinders, 10·52 in.; stroke of all pistons, 30 in.; clearance, high-pressure cylinder, 4 per cent.; low, 3·7 per cent. Diameter of rods, 2¼ in. Ratio of volumes of cylinders, 4·085. Average cut-off in high-pressure cylinders, one-fourth, and in low, one-third. Jackets envelop the barrels, but not the heads, of both cylinders, and steam of full boiler pressure is used in each. The heads are not jacketed, but contain passages leading to and from the ports. The condensed steam from the jackets is pumped into the feed pipe at a point between the boiler and hot well. The condensed steam collected in the receiver is received in a trap, and continuously pumped through a heater placed in the chimney flue, and thence returned to the

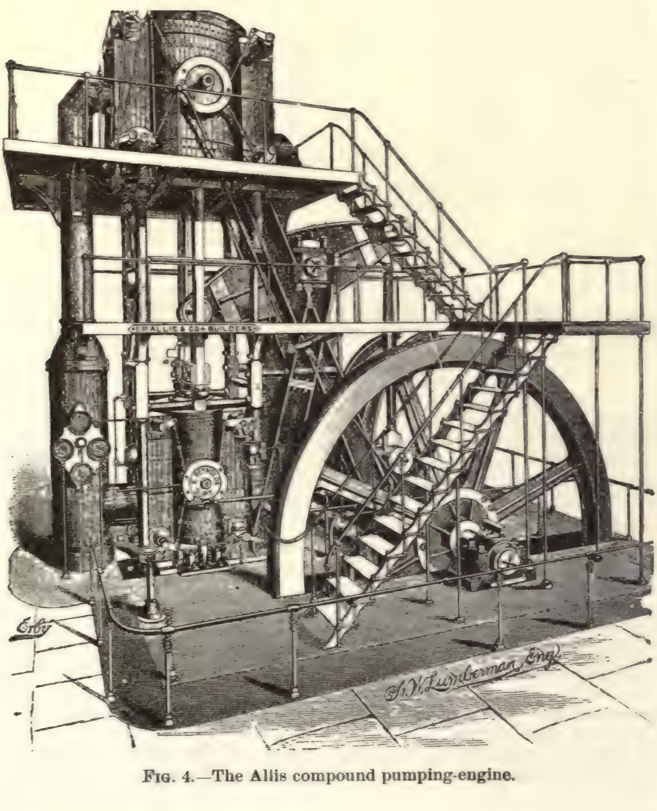


Fig. 4.—The Allis compound pumping-engine.

top of the receiver. Out of a total of about 155 lbs. thus circulated per hour, in actual work, one-third only is evaporated and returned to the receiver as steam; the other two-thirds gradually accumulates in the receiver and is blown to waste every three hours.

In June, 1889, a test of this engine was made by Prof. James E. Denton, who says concerning it: The boiler evaporates 8·88 lbs. of water from 104° F. into steam of 127 lbs. pressure with anthracite coal yielding 14 per cent. of ashes at 5 lbs. rate of combustion, and 9·35 lbs. of water from 104° F. with Georges Creek bituminous coal yielding 10 per cent. of ashes at 5 lbs. rate of combustion. The engine performs a horse-power of work in its steam-cylinders with a consumption of 13·75 lbs. of steam per hour. Taking into account the percentage of ashes, the performance of the boiler is practically the maximum economy to be expected or gotten from boilers, while the steam consumption of the engine is also unexcelled, as even the most approved marine engines of the triple-expansion type, using steam at 150 lbs. pressure, have yet to produce a record of steam consumption lower than 15 lbs. of steam per hour per horse-power. The combined efficiency of the boilers and engines give a horse-power in the steam-cylinders with 1·54 lbs. of anthracite coal consumed per hour, and 1·48 lbs. bituminous coal consumed per hour. Out of a horse-power produced in the steam-cylinders, 95 per cent. is available to force water, only about 5 per cent. being required to overcome the friction of the mechanism and operate the air-pump. In this respect also the engine is an extraordinary piece of apparatus. It results from all of the foregoing that the duty per 100 lbs. of coal was for anthracite coal, 124,750,000 ft. lbs., and the duty per 100 lbs. of coal was for bituminous coal, 127,350,000 ft. lbs. These figures are for the actual evaporation of the boilers as given above. This engine made an average duty record for the entire year 1888 of 124,512,184 ft. lbs. per 100 lbs. of coal used.

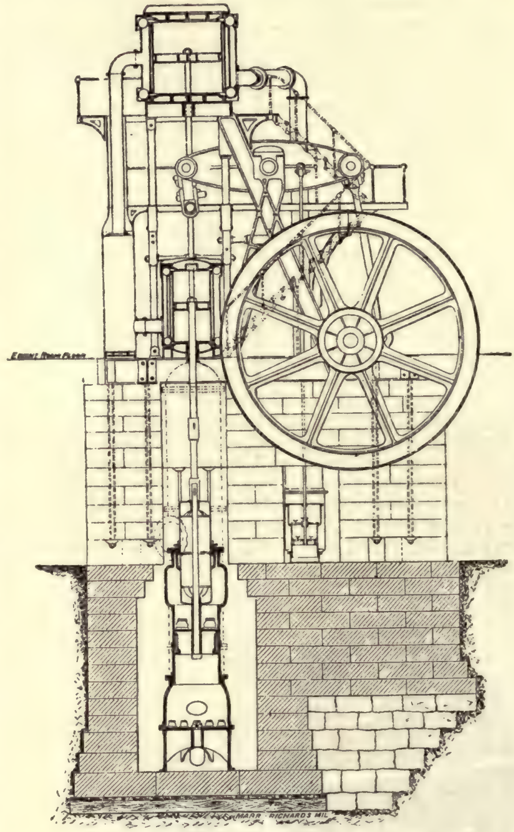


FIG. 5.—The Allis compound pumping-engine.

Allis's Compound Vertical Pumping-engines.—Figs. 4 and 5 illustrate a pumping-engine constructed by E. P. Allis & Co., of Milwaukee, for the city of Milwaukee. The low-pressure cylinder is placed on the top of the wrought-iron framework, and directly central over the high-pressure cylinder, which is on a level with the engine-room floor, the pistons of the two cylinders being connected by two piston-rods. The rod for operating the bucket and plunger pump is fastened to the high-pressure piston and extends through a stuffing-box in the bottom head to the bucket and plunger pump placed in the pump pit. By this means all the steam-cylinders are coupled solidly to the pump plunger. Both steam-cylinders are steam-jacketed and furnished with a device for regulating the point of cut-off and speed of the engine. The following are the principal items of interest from a test trial: Duration of trial, 48 hours; steam pressure in engine room, 74·81 lbs.; vacuum by gauge, 26·25 in.; water-pressure gauge, 62·02 lbs.; total head, including suction lift, 67·29 lbs.; revolutions of engine per minute, 25·51; piston speed per minute, 255·10 ft.; coal consumed, 32,395 lbs.; duty in foot pounds per 100 lbs. of coal consumed, 104,820,431. The test was made under the ordinary every-day conditions, and the actual weight of coal consumed was charged up without deductions of any kind. This engine raised 12,000,000 gallons 150 ft. high in 24 hours.

Reynolds' Screw Pumping-engine.—One of the most novel forms of pumping-engine that have been built in recent years is that shown in Fig. 6, designed by Mr. Edwin Reynolds, superintendent of the E. P. Allis Co., for flushing the sewer tunnels of the city of Milwaukee. The pump is a form of propeller-wheel, with screw-shaped blades. This is mounted in a

cast-iron circular housing or casing set in the brick walls of the tunnel. The wheel is keyed to the crank shaft of the Reynolds vertical compound condensing engine. Bearings for supporting the outer end of the shaft are formed in the wheel casing. In tests of the engine the duty was computed from the quantity of water discharged through the tunnel, and the total amount of coal fired to the furnaces, without deductions or allowances of any kind. The quantity of water discharged was determined by injecting bright carmine coloring matter into the center of the water current in the tunnel and noting the time elapsing before the coloring appeared at the discharge outlet, 2,534 ft. distant. These tests were repeated to establish a fair average of the quantity of water discharged per revolution of the

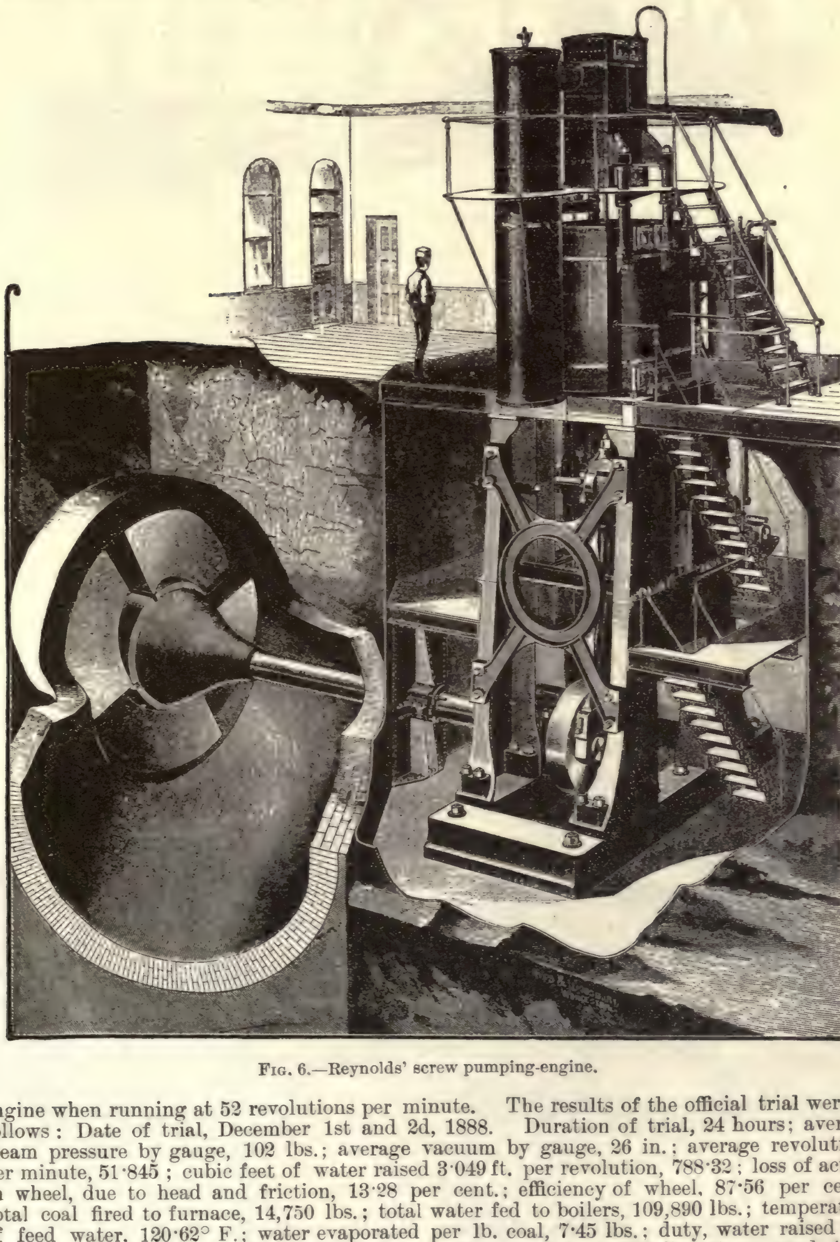


Fig. 6.—Reynolds' screw pumping-engine.

engine when running at 52 revolutions per minute. The results of the official trial were as follows: Date of trial, December 1st and 2d, 1888. Duration of trial, 24 hours; average steam pressure by gauge, 102 lbs.; average vacuum by gauge, 26 in.; average revolutions per minute, 51·845; cubic feet of water raised 3·049 ft. per revolution, 788·32; loss of action in wheel, due to head and friction, 13·28 per cent.; efficiency of wheel, 87·56 per cent.; total coal fired to furnace, 14,750 lbs.; total water fed to boilers, 109,890 lbs.; temperature of feed water, 120·62° F.; water evaporated per lb. coal, 7·45 lbs.; duty, water raised per 100 lbs. coal used, 75,944,424 ft. lbs.; duty, water raised per 1,000 lbs. steam used, 101,936,504 ft. lbs.

Geared Mine Pump.—Fig. 7 shows type of pumping-engine built by E. P. Allis & Co., and used for pumping out mines. The top of the "bob" is shown projecting through the

floor; this is made to fit any location or conditions. The rods connecting the "bob" with the pumps and crank are made any size or length, depending on the depth of the shaft and its distance from the engine; these rods are supported by trucks and rollers or carrier arms as desired. The common design of single-acting Cornish pumps is usually adopted for this service. The pumps are driven by a Reynolds Corliss engine, by means of a shrouded step

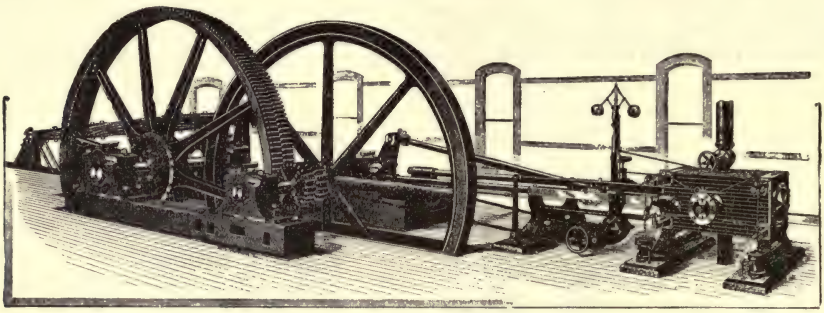


FIG. 7.—The Allis geared mine pump.

tooth pinion and gear of such proportions that the engine will run at a fair rate of speed while the pump plungers move at a slow speed when running at rated capacity.

Electric Pumps.—The numerous applications of electricity to pumping purposes which have been made during the last five years simply amount in most cases to the attachment to any form of pumping machine of an electric motor. Quite recently such applications have been made to heavy pumping, as for water-works, deep mines, etc. In the latter the power is transmitted from the electric generator on the surface to the motor at the bottom of the mine

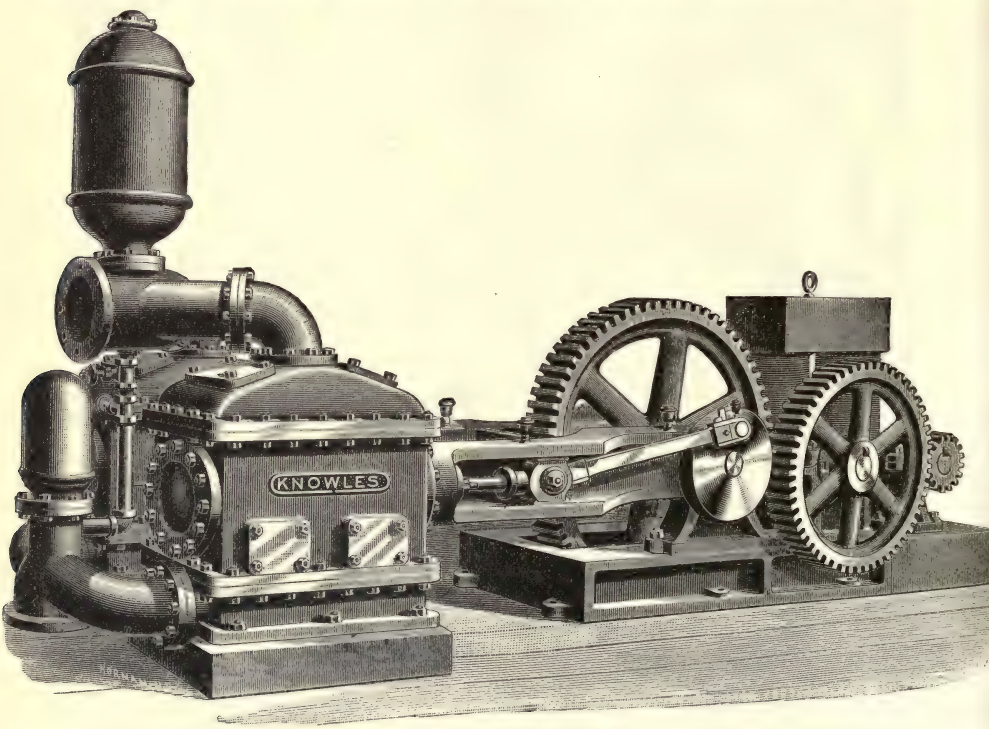


FIG. 8.—Electric-motor pump.

through copper wires or rods, thus dispensing with the cumbrous reciprocating pump-rods used in the Cornish system of mine pumps, or with the steam pipes used with direct-acting steam-pumps. Fig. 8 illustrates an electric motor applied to a duplex water-works pumping-engine. The motor is of the Edison vertical type, arranged with insulated pinion, etc. The water end of the machine is the usual water-works type, having composition plungers work-

ing through composition sleeves. The suction valves being placed below and the discharge valves above the plungers, gives the room necessary for a very large amount of valve area and water passages. This reduces the friction of the water as it passes through the pump to a minimum. There is a connection between the discharge of the pump (immediately under the air chamber) and the suction-chamber with a gate valve on same; the object of this arrangement is that when starting up the pumping-engine the pressure on the pump can be taken off the valves by letting the water flow back into the suction. The check valve on the discharge nozzle, which is necessary to this arrangement, is not shown by the illustration.

Duty Trials of Pumping-engines.—A committee of the Society of Mechanical Engineers, appointed in 1890 to report on a method of duty trials of pumping-engines, recommended that the old unit of duty per 100 lbs. of coal be abolished, and a new unit of 1,000,000 heat units be used in its place. This corresponds to the heat obtained from 100 lbs. of coal which develops 10,000 heat units per lb. The committee give full and explicit directions as to the method of making the various observations, as to the arrangement and use of instruments, and other provisions for the test. The complete report is published in Vol. XI. Trans. A. S. M. E., and it should be carefully studied prior to making preparations for a test.

PUMPS, ROTARY. *Centrifugal Pumps.*—A paper by John Richards, of San Francisco, published in the Proceedings of the Institution of Mechanical Engineers, February, 1888, contains much valuable information on the subject of centrifugal pumps. We abstract from it as below:

Elsewhere it has not been common to recommend centrifugal pumps for high lifts, and they have been considered less economical than piston pumps; but the opinions hitherto entertained regarding them have been much modified by their work in California. A head of 100 ft., however, for a centrifugal pump to work against is a very different thing from a head of only 10 ft.: the impact or mechanical push of the vanes, which is a very important factor, diminishes as the head increases, and as the speed of the tips of the vanes exceeds that of the water in the volute casing. When the head exceeds 40 ft., efficiency declines rapidly, but not to such an extent as to outweigh the great economic advantages of centrifugal pumps for heads up to 100 ft. or even more. For lifting water from the gravel strata in California, four kinds of centrifugal pumps have been employed, namely: firstly, the common make with open vanes revolving in a plain volute casing; secondly, wheels with shielded or encased vanes, the water being drawn in at the center and discharged from the circumference; thirdly, compound pumps with two or more wheels acting in succession upon the water during its passage through the pump; and, fourthly, balanced pumps receiving the water at one side, whence it is deflected in an easy curve to the circumference by a conical disk on which are formed the vanes. These various forms of the centrifugal pump may be regarded as phases of development, adapted in some cases for particular objects, but generally reverting from encased vanes, compound or double wheels, and other features, back to the original simple form of the first pumps in use prior to 1820. The wheels with encased vanes, for example, have been a feature of the earlier practice with most prominent makers. These wheels were made in America as early as 1831, mainly with the object of partly avoiding side thrust when a single inlet was employed

Centrifugal Pumps with Open Vanes.—These were at first employed for lifts up to 30 ft., and were usually arranged, as shown in Fig. 1, at the bottom of rectangular pits sunk to the depth required for bringing the pumps within suction distance of the water. The pits have often to be sunk 50 ft. or more below the surface, and are usually 10 to 12 ft. long, and 4 to 6 ft. wide. The pump, *P*, is driven by a vertical shaft, which is mounted in pivoted bearings, each having a supported collar for carrying the weight of the shaft and pump wheel.

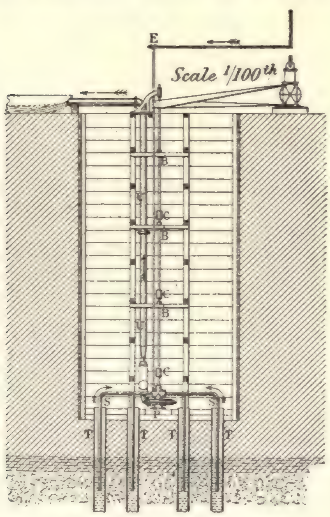


FIG. 1.—Centrifugal pump in pit.

Centrifugal Pumps with Shrouded or Encased Vanes.—Nearly all makers of centrifugal pumps in California and elsewhere have at first followed Sir Henry Bessemer's plan of more than 30 years ago (Proceedings, 1852), employing a shrouded wheel, in which the sides of the vanes, *V*, are attached to two enclosing disks that revolve with them, as shown in Fig. 2, and in the plan of the wheel, Fig. 3. The difference is very great between a wheel or runner constructed in this manner with closed sides, and an open wheel without enclosing disks attached to the vanes. With the shrouded wheel a water-tight joint must be maintained all round the inlet orifice, otherwise the water would only circulate through the pump, passing from the circumference back to the inlet. Such leakage is increased by the pressure, which at all points on the sides of the wheels is the same as in the discharge pipe or at the discharge orifices of the wheels. The skin friction of the water is no less with a shrouded wheel; the water instead of being driven round in contact with the sides of the stationary casing, flows through

the wheels as it does through the pipes, without any greater skin friction in passing through the wheel than for an equal distance in the pipes; but on the other hand there is an equal skin friction of the outside of the wheel itself. The latter has been found to be diminished by having a considerable thickness of water intervening between the outside of the revolving wheel and the inside of the stationary casing. In the pump shown there is only a very narrow clearance space at the sides of the wheels; but here unusual care has been taken in construction, the wheel being turned and made perfectly true after being keyed on the spindle.

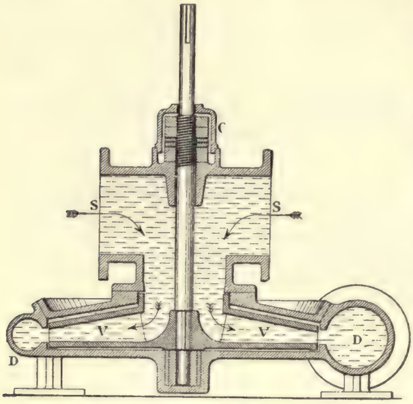


FIG. 2:—Centrifugal pump. Section.

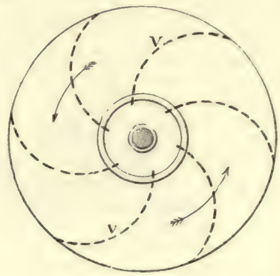


FIG. 3.—Plan of wheel.

The resistance greatly increases if the wheels are not perfectly true; but up to the present time the data respecting friction in such cases are meager. As the water enters through one side only of the wheel, it causes a thrust in that direction which is equivalent not to the force of the suction only, as is generally supposed, but to the area of the inlet multiplied by the maximum pressure of the discharge. The pump being inverted, with the suction inlet at the top, the entering water flows downward, and the reactive force is consequently upward. The upward thrust, which in most cases would be objectionable, is here turned to practical account for supporting the weight of the vertical driving shaft and the pump-wheel. The plan of inverting the pump so that the suction enters at the top was introduced in California by the writer in the latter part of 1883, and was then believed to be of great importance, because of the difficulty of supporting the vertical driving shafts by other means in the deeper pits. In the case of one pump, completed in 1886, the weight of the shaft and its attachments was nearly 2,000 lbs. The shaft was of steel, $2\frac{1}{4}$ in. diameter, and ran at 600 revolutions a minute. The upward thrust was sufficient to carry this shaft, together with some additional weight which was found necessary. The lift was 90 ft.; inlet of pump, 10 in. diameter; throat of discharge, 5 in. diameter; uptake pipe, 10 in. diameter. This problem of thrust upon enclosed wheels taking water at one side is an intricate one. If the rear side of the wheel is exposed, as is common, to a pressure equal to the discharge, the thrust, as already stated, is equal to the inlet area multiplied by the discharge pressure. If the wheel is shrouded on one side only, the thrust will be equal to the whole area of the wheel multiplied by the discharge pressure. At starting there is, of course, no upward thrust until the pump is charged. Provision is, therefore, made at *C* for carrying the shaft on collars, which are already required for steadying the revolving wheel laterally in the pump casing, and are so arranged as to support the shaft vertically for a short time, unassisted by the water thrust. The collars are screwed upon the shaft, and several thin washers of steel are inserted between them and the seat which carries them. They run in a pool of oil, or rather oil and water, because there is generally a small pipe leading a little water back from the discharge pipe, *D*, to the thrust box, *C*. The joint thus formed seals the pump, taking the place of a packing gland. The suction pipes, *S S*, are shown as they are commonly arranged, for branches leading in from right and left; their large area is intended to be equal to that of a number of branch pipes, and to keep the flow in all at a uniform rate as nearly as possible.

Compound Centrifugal Pumps.—Two of the main problems to be dealt with in applying centrifugal pumps to high lifts are how far the impact or mechanical push of the vanes may be disregarded as a factor in the pump's duty, and how the bearings and driving gearing may be maintained in proper order at the high speed required.

Practically the speed at which the pump should be driven increases as the square of the height of lift. For example, the circumferential speed of the revolving wheel for a lift of 60 ft. will be at least six times as fast as the discharge column should flow; while for a head of 80 ft. the circumferential speed for the same flow would have to be more than ten times that of the discharge current. It is, therefore, seen in how rapidly increasing a degree the revolving wheel must overrun the flow as the lift increases; and how rapidly the effect due to impact or mechanical push of the vanes falls off, as the velocity of the wheel increases. For lower lifts the extent of overrunning diminishes in the same degree, and the gain by impact is increased accordingly. It is easy to attain high efficiency in centrifugal pumps working against a low head; but it is a difficult matter to arrange such pumps suitable for working in the deep pits in California, against a pressure of 43 lbs. per sq. in., or 100 ft. total lift, and to secure results that are satisfactory. Thus far it has not been possible to make experiments for determining definitely the efficiency attained in these high lifts. From

such observations as have been made it would seem that from 35 to 45 per cent. of the indicated power has been realized in water raised.

Some of the pits at first made were too narrow to admit pumps with volute casing and with a single wheel large enough to attain the required speed. In such cases the pumps have been compounded, as shown in Fig. 4, so as to reduce the speed of rotation and diminish the size of the wheels and casing. In the compound pump here shown, with two revolving wheels, *R*, the main casing is made in five parts, consisting of three hoops or rings, and two intervening diaphragm plates, all secured together by external bolts. The driving shaft from the top of the pit is coupled to the pump spindle at *C*. A charging pipe, *P*, is carried down from the top of the pit, as in the case of Fig. 1, previously described. The foot of the delivery main, *M*, is surrounded by an annular air-vessel, *A*. The water is drawn by suction into the top chamber, *T*, whence it passes downward through the two wheels or runners, *R*, and out through the discharge chamber *D*, the delivery valve *V*, and the rising main, *M*.

The two shrouded wheels have each five curved vanes, as shown in the plan, Fig. 7. The exact shape of the curves is believed by the writer to be a matter of very little importance in practice; and the number of the vanes, whether two or six, does not make much difference in a high-speed pump. Curved throat pieces and tangential tips to the vanes are found in such cases to be of practical value so far only as they tend to obviate friction and consequent slight loss of power. The diaphragm above the upper runner is a plain flat plate; but the intermediate diaphragm between the two runners is made with fixed guide blades on its upper side, for leading the water back from the circumference of the upper wheel to the central inlet into the lower. Besides the double inlet at *S S*, two more inlet orifices are pro-

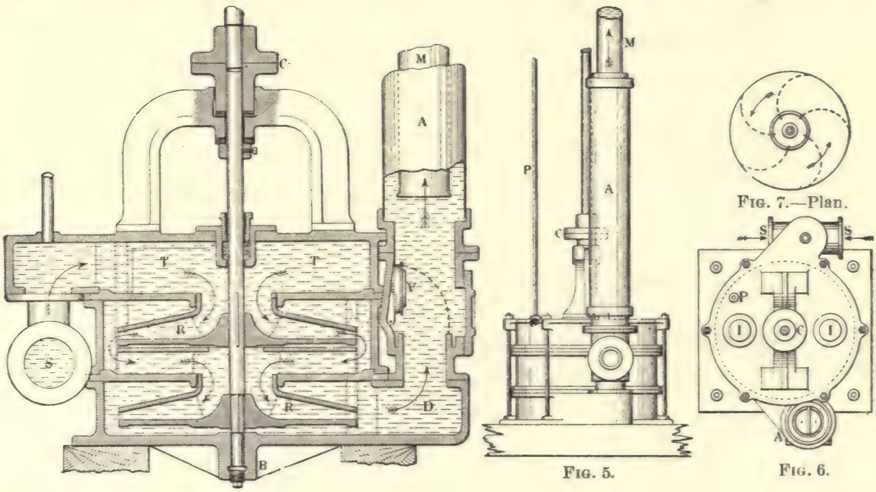


Fig. 7.—Plan.

Fig. 4. Fig. 5. Fig. 6.

Irrigating machinery.—Compound centrifugal pump. Details.

vided in the top cover at *I I*, Fig. 6, for convenience of attaching additional suction pipes in different cases; but it is not often that all four inlets are required. The delivery valve is arranged to swing clear of the ascending column of water; the area of passage is here contracted and determines the pump's capacity. In all other parts the area of passage is made much larger. Except for avoiding concussion from the water in stopping the pump, the air-vessel, *A*, may seem superfluous in a continuously acting pump; but it is not so, and air-vessels are now applied by the writer in all cases for deep pumping. The seat of the delivery valve, *V*, is raised so as to leave an annular space all round it, for catching any gravel deposited in the valve chamber; this space is commonly made much larger than shown in the drawing. The bottom bearing of the pump spindle at *B*, Fig. 4, is simply a hole bored in the base plate. There is no strain upon it when the wheels are carefully balanced. It is, of course, exposed to sand and gravel, but these do not seem to have much effect upon bearings of steel running in cast-iron; either the sand is at once pulverized and washed out, or in some other way attrition is prevented. Similarly the throats of the inlet orifices in the revolving wheels do not seem to wear after they have worn themselves out of contact.

Balanced Pump with Single Lateral Inlet.—In Figs. 8 and 9 is shown the construction now adopted by the author for pumps with a single inlet at one side, a form most suitable for the requirements of the Pacific Coast, and essential in many cases. The drawing shows a pump of 12-in. bore arranged for a head of 30 ft. The wheel consists of a curved disk, *D*, shaped so as to deflect the water gradually from the center to the circumference. On the face of the disk are formed the vanes, *U* and *V*, of unequal area. On the back of the disk are also vanes, *N*. Holes, *C*, are made through the disk, so that any water passing over the circumference may circulate in this way. An equal or nearly equal centrifugal action is thus set

up on each side of the disk, and there is no axial thrust, the pump being balanced in the same way as though there were double inlets, one at each side. In this arrangement the suction pipe is easily removed, and can be hoisted vertically clear of the pump. The water passages are also more free, and of large area until the disk is reached. In order to guard

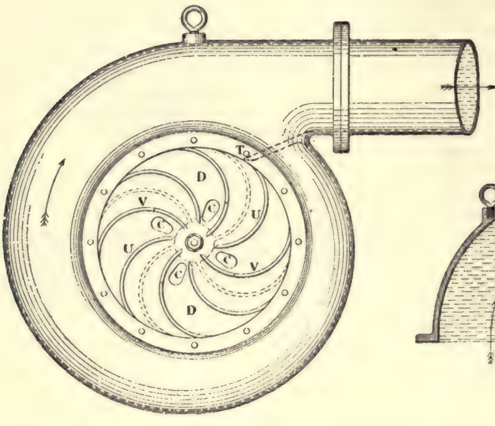


FIG. 8.—Side elevation.

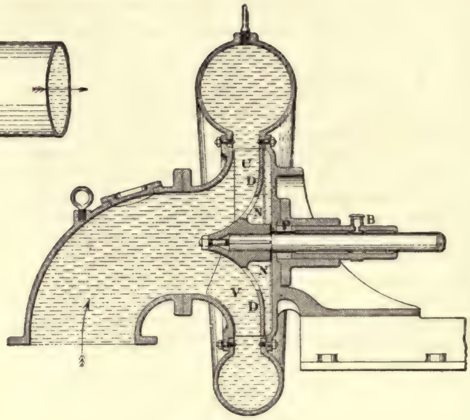


FIG. 9.—Section.

Balanced centrifugal pump.

the spindle bearing from sand and grit, the packing is placed at P, inside the main bearing B, which acts also as a gland for compressing the packing. This arrangement is now employed in all the various modifications of centrifugal pumps from the author's designs, and in working permits no leak of either air or water, and the packing seldom needs renewal. The pumps are characterized by great steadiness of running, and an absence of the pulsation or jar common with free or open vanes, or with shrouded wheels. Such jar is often caused by an obtuse or imperfectly formed throat-piece at T, especially with shrouded wheels, the radial flow being interrupted at that point.

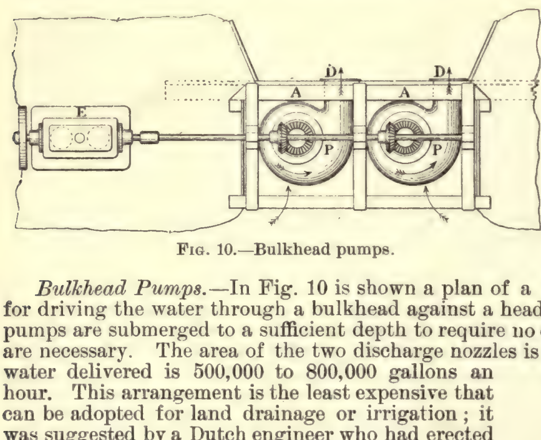


FIG. 10.—Bulkhead pumps.

Bulkhead Pumps.—In Fig. 10 is shown a plan of a pair of centrifugal pumps arranged for driving the water through a bulkhead against a head varying from nothing to 10 ft. The pumps are submerged to a sufficient depth to require no charging, and consequently no valves are necessary. The area of the two discharge nozzles is 150 sq. in. each, and the quantity of water delivered is 500,000 to 800,000 gallons an hour. This arrangement is the least expensive that can be adopted for land drainage or irrigation; it was suggested by a Dutch engineer who had erected similar works in Java, and has been found in every way satisfactory. The embankment is cut through, and a strong timber bulkhead, A, is erected across the gap. The pumps, P P, are placed immediately behind the bulkhead, with their discharge nozzles projecting through it. Flap valves opening outward are hung over the discharge nozzles at D, to prevent back-flow through the pumps when not working; in dry seasons they are sometimes opened for letting water flow through for irrigation. The vertical pump spindles are driven by bevel gearing from a horizontal shaft. The engine, E, is single acting, with two cylinders of 10 in. diameter, and its speed is 300 revolutions per minute. The machinery shown in Fig. 10 was erected during 1885, on the Sacramento River, 75 miles from San Francisco, for draining tule lands.

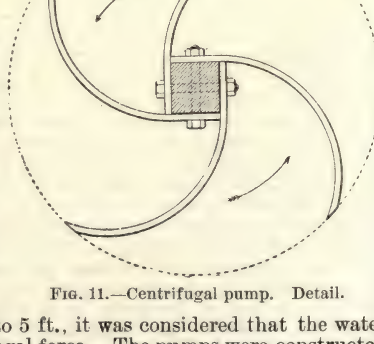


FIG. 11.—Centrifugal pump. Detail.

The average head in this case being only from 3 to 5 ft., it was considered that the water could be driven more by direct push than by centrifugal force. The pumps were constructed

accordingly with smooth iron vanes, bolted to a square extension on the pump spindle, as shown in Fig. 11. The throats of the suction inlets were made very sharp, and brought in as close as possible to the inner tips of the vanes. In the writer's opinion the effect would have been much the same, or, perhaps, even better, if the volute casing had been replaced by the ordinary concentric casing. When a good turbine water-wheel will realize a duty of 70 to 80 per cent. by the direct pressure of the water, there seems no reason why a centrifugal pump, considered as a turbine-wheel, acting in the reverse manner, should not utilize, in some near proportion, the power applied to it for moving and raising water. The writer is not aware whether any investigations have been made in this direction; but there appears to him to be a close analogy between the two cases, at least for low heads.

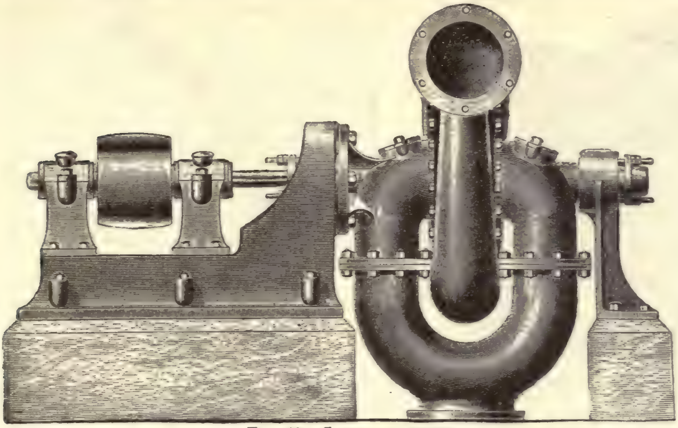


Fig. 12.—Lawrence pump.

The Lawrence Centrifugal Pump.—Figs. 12 and 13 show a centrifugal pump built by the Lawrence Machine Works, Lawrence, Mass. The base and shaft supports are cast separate. The latter being bolted to the base, enables one to remove the pulley or babbitt the boxes without disturbing the other parts of the pump. Larger sizes are constructed with two covers, so that the relative

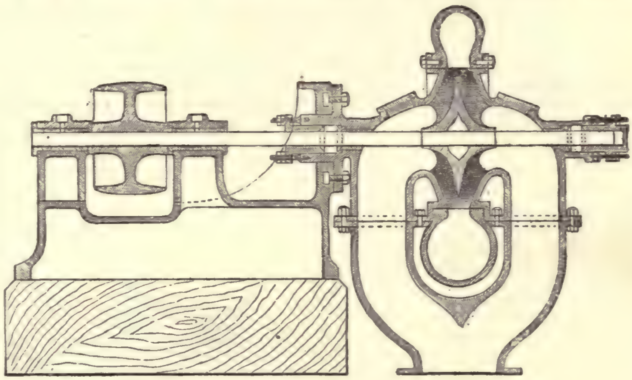


Fig. 13.—Lawrence centrifugal pump. Section.

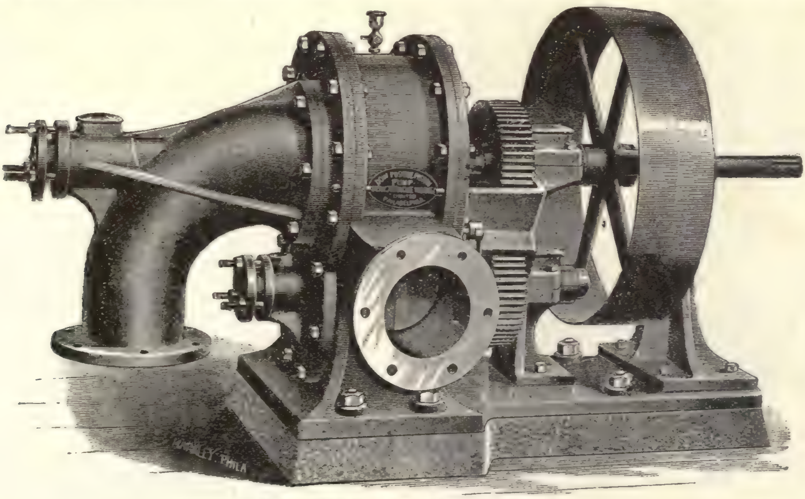


Fig. 14.—Dow's positive-piston pump.

position of suction and discharge can be easily changed, by removing the bolts that hold cover to volute and turning the latter around as many bolt holes as desired ; or may be changed from a right to a left hand pump, or vice versa, by turning the volute face about, and, of course, the disk changed about on the shaft also to correspond. A test made in 1890 by Mr. George H. Barrus of a 24-in. Lawrence centrifugal pump in Montreal gave a result of 61·3 per cent. efficiency.

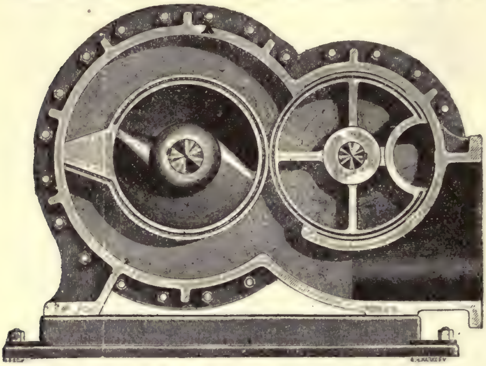


FIG. 15.—Section through pump chamber, Dow's positive-piston pump.

ROTARY PISTON PUMPS.—*Dow's Positive-Piston Pump*, as built by the Kensington Engine Works, Philadelphia, is shown in Figs. 14, 15, and 16. This pump produces suction and forcing by the rotary movement of a piston. The work is done in two annular chambers, surrounding an internal cylinder, and separated by a central partition. In each of these chambers moves a single piston with its supporting wings, making the pump duplex in its action. The pistons are so placed that a balance of all the parts, and of the fluid moving through them, is maintained. The suction is central, passing through the internal cylinder which is attached to and revolves with the main shaft. This cylinder supports the pistons, and has openings behind them, between their strengthening wings. Screw propeller-shaped blades lead to these openings, through which the fluid passes drawn by action of the pistons, which, in their travel, cause a suction in the same manner as with a reciprocating plunger, the ends of the annular chambers being completely closed by the abutment cylinder, which is in close contact and revolves in equal time with the piston cylinder, the closing being aided, when necessary for very high heads or use as a fire pump, by packing. The movement of the fluid is aided as it flows through the internal cylinder from the center outward to the annular chambers by the suction blades, and by centrifugal force. Whilst the suction is taking place continuously behind the pistons, the contents of the chambers before them are being continuously forced through the discharge pipe in a freely open course, and in a tangent to the action of the pistons. The discharge is entirely unobstructed (and equal to the displacement) except while the pump is being used upon air alone as in obtaining suction, when to control the great elasticity of air, two hinged valves, one for each chamber, are dropped upon their seats in the discharge opening ; upon the current being established, these valves are raised and held completely out of it, they being no longer necessary. The gears are used only to secure synchronous motion to the abutment and piston cylinders, all the power for the work accomplished being applied directly to the pistons through the main shaft. The case is made air-tight through the use of stuffing-boxes. The moving parts have no frictional contact with the case, or with each other, and the wear is almost entirely confined to outside journals, and therefore readily controlled.

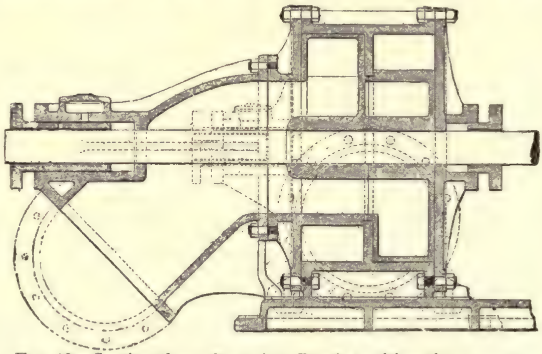
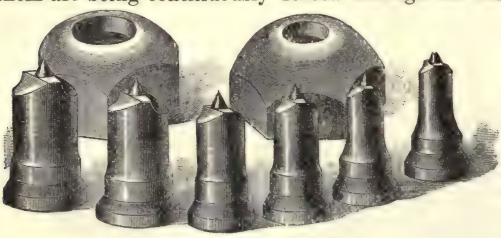


FIG. 16.—Section through suction, Dow's positive-piston pump.



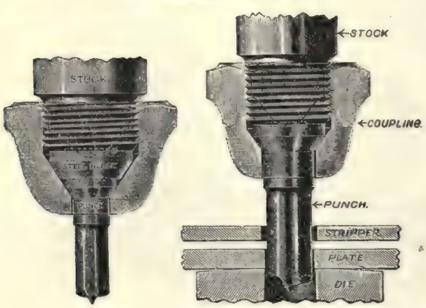


FIG. 1.—Reducing couplings.

Pumps, Steam Fire : see Engines, Steam Fire.

PUNCHING MACHINES. *Reducing Couplings for Punches.*—Fig. 1 il-

lustrates a system of reducing couplings, manufactured by the Pratt & Whitney Co., by which

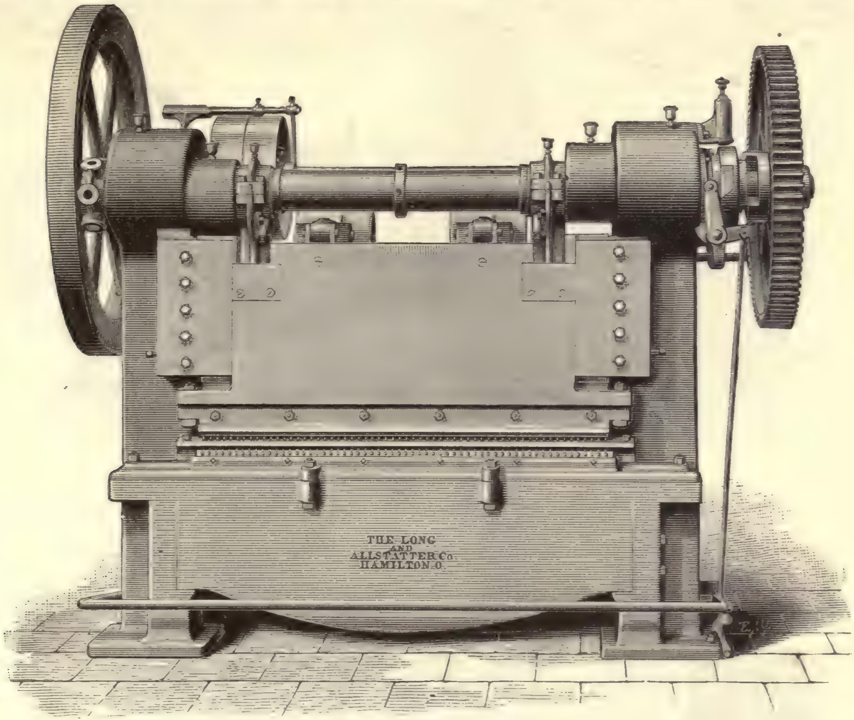


Fig. 2.—Multiple punch.

punches of short lengths and small diameter can be adjusted to stocks made for larger punches. Heretofore the changing of punches of large diameters for smaller ones has neces-

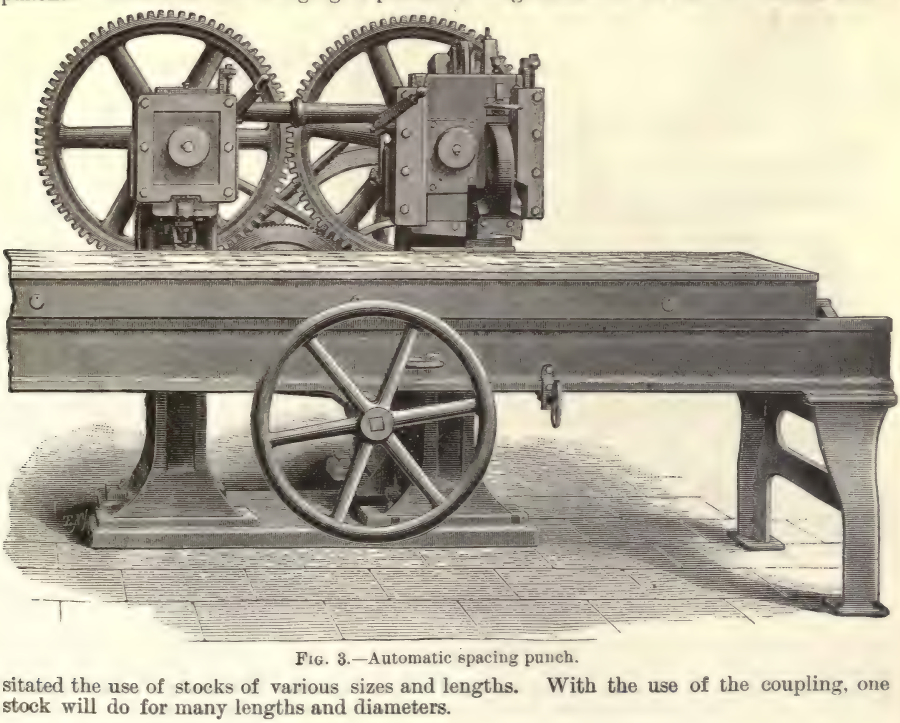


Fig. 3.—Automatic spacing punch.

sitated the use of stocks of various sizes and lengths. With the use of the coupling, one stock will do for many lengths and diameters.

The distance from point of punch to coupling *is the same*, whether long, short, or regular coupling is used.

Multiple Punch.—Fig. 2 shows a machine built by the Long & Allstatter Co., of Hamilton, O., for punching long rows of holes at one stroke. The gang-punch and die can be quickly

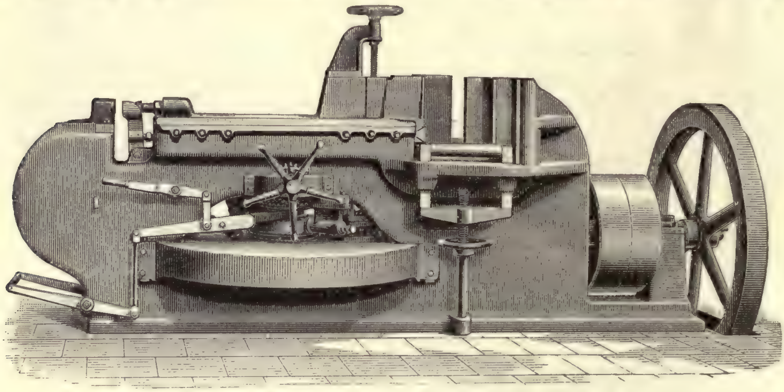


Fig. 4.—Punch and straightener.

removed for changing. The cut shows machine set to punch a 5-ft. row of 60 one-quarter-inch holes through one-quarter-inch metal.

Automatic Spacing Punch.—Fig. 3 shows an automatic trimmer, beveler, spacer, and

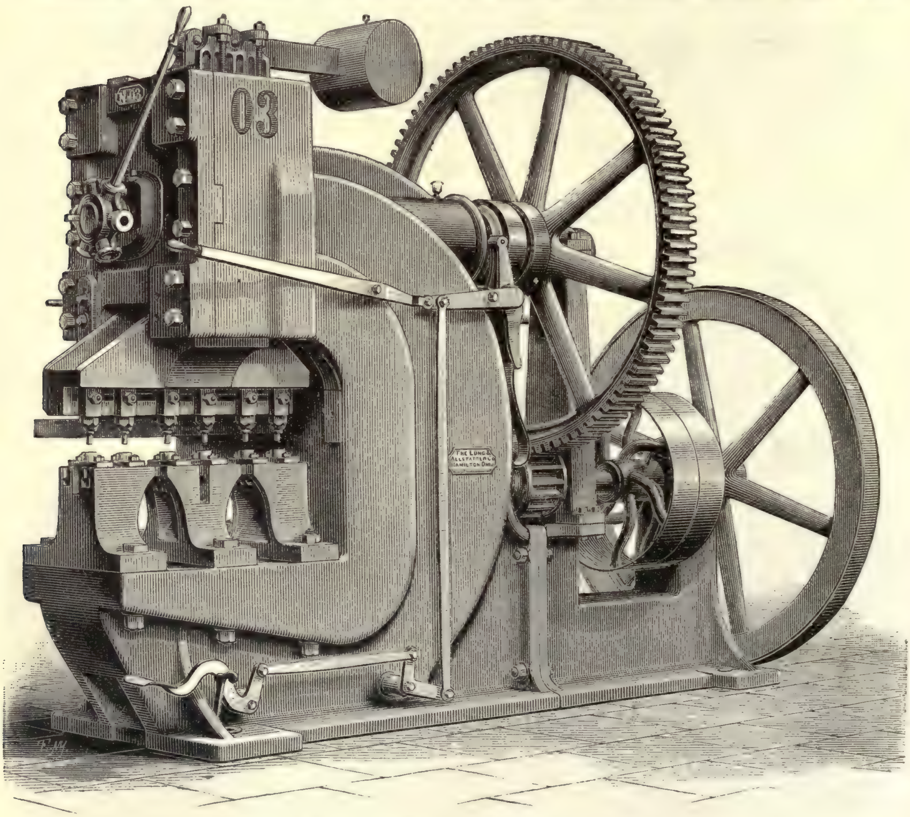


Fig. 5.—Multiple and I-beam punch.

punch, made by the same company. It is designed to trim, bevel, space, and punch the holes in boiler and other plate work. The sheet is fastened to the table and fed past the tools, which trim and bevel the edge, and automatically space and punch the holes. The spacing is adjustable. The table has quick hand motion in addition to the power-feed motion.

Combined Punch and Straightener.—Fig. 4 shows a horizontal beam punch combined with a straightener, also made by this company. The main driving shaft, acting through a bevel gear, drives the large horizontal wheel which through a cam shaft drives the sliding head, one end of which carries the punch, and the other a straightening block or die. The machine is designed for bridge, girder, and general beam work, and will punch holes in $1\frac{1}{2}$ in. plate and straighten 15-in. beams. The straightening die is adjustable while in motion.

Multiple and I-Beam Punch.—Fig. 5 shows a heavy multiple and I-beam punch made by the Long & Allstatter Co., for punching, at one stroke, one or more holes in the flanges or two beams at once. It is designed for bridge and girder work, etc., and receives beams 12 to 20 in. deep. It can be used for general flat punching without removing the special die-blocks.

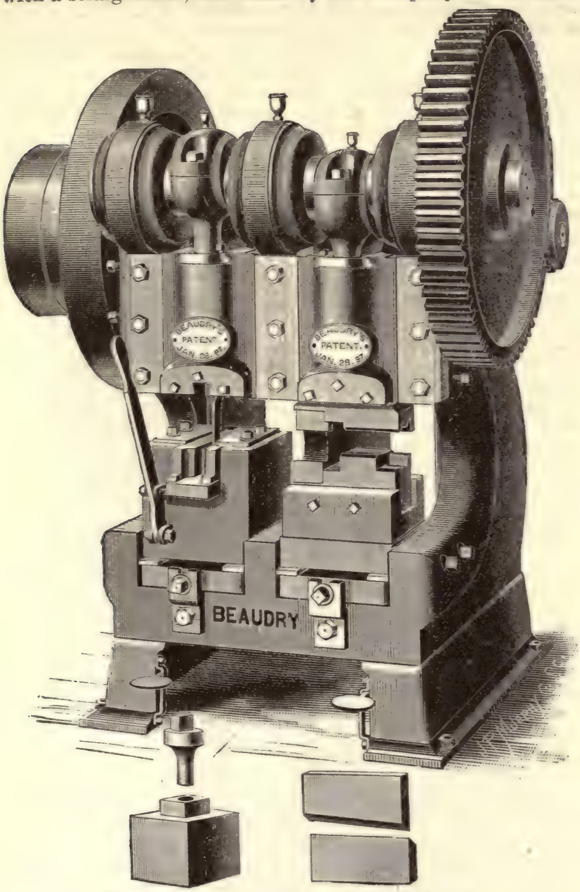


Fig. 6.—Duplex punching and shearing press.

Beaudry's Duplex Punching and Shearing Press.—Fig. 6 represents a press made by Alex. Beaudry. It has two plungers on one crank shaft, so connected that either plunger may be worked independently, or they may be run together, or either may be used as a shears or press or punch, while the other is in use for the same or other purposes.

The Hilles & Jones Punch.—Fig. 7 represents a horizontal punch, made by Hilles & Jones Co., of Wilmington, Del. It has a deep throat or jaw that can be used for flanges as well as plain

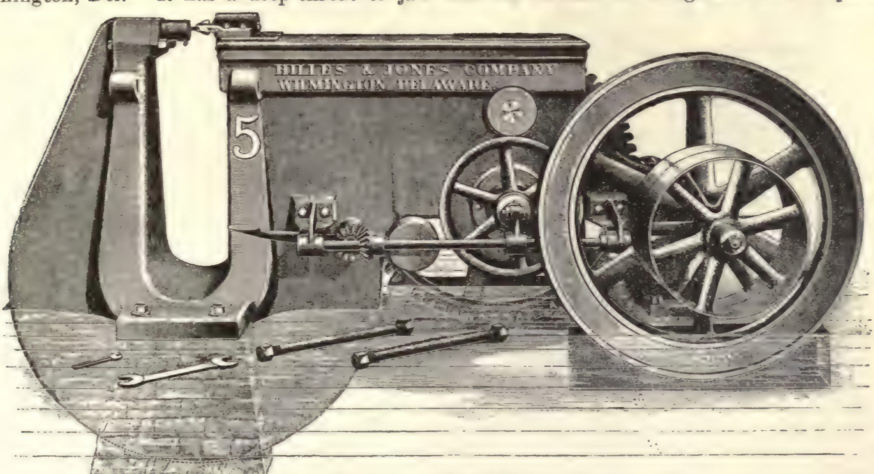


Fig. 7.—Horizontal punch.

punching. The gearing and fly-wheel being below the top of the machine, leaves it perfectly clear, so that flanges, heads, or crooked furnace plates, as well as bent angle-iron, may

be punched from either the inside or outside. This is a convenient tool for punching brace or stay-bolt holes in locomotive boilers. Plates that are already bent and fitted up can be taken down and every hole punched, thus saving the time spent in drilling or cutting holes by hand. The hand wheel is used for placing the center of the punch to the center mark on the work before throwing in the clutch ; in this way punching can be done as true and correctly as drilling. The stripper is adjustable for all thicknesses of iron.

Purifier : see Heaters, Feed-water, Milling Machinery, Grain and Oil Purifiers.

PURIFIERS, OIL.—*The Grosche & Bigler Oil Purifier,* shown in Fig. 1, is used for taking dirt out of oil after it has been used in lubricating machinery. The action of the purifier is based on the relative difference in the specific weight of oil and water. The oil is placed in the upper chamber and runs through the center tube, below the water, passes around the steam coil, and now being somewhat diluted by being warmed, will drop its impurities, and after going once more down through chamber, again up through chamber, once more through water, then through the discharge pipes, it will finally gather above the water-line ready for use. The blow-off pipe answers as an outlet for any gases that may form ; it will also prevent overflowing by discharging any rising or overheated oil back into reservoir. The steam-pipe serves to blow out and clean the whole apparatus from time to time, as well as to warm the oil.

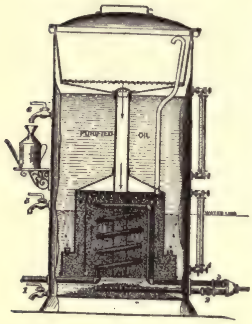


FIG. 1.—Oil purifier.

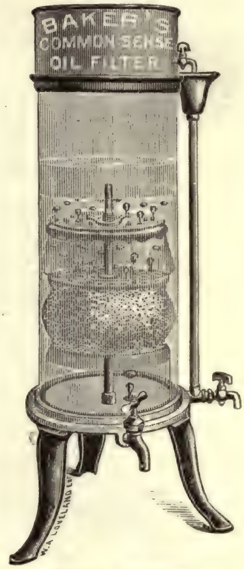


FIG. 2.—Oil filter.

The Baker Oil Filter is shown in Fig. 2. The oil enters at the bottom, passes into a body of water, and floats upward through the chamber of filtering material, as shown in the cut, and settles above the water. Centrifugal machines especially constructed for the purpose are commonly used for extracting oil from filings, shavings, etc.

PYRO-ENGRAVING.—A new process of engraving, which consists in tracing, by means of an incandescent point, upon wood, leather, bone, ivory, fabrics, etc., designs which, varied in tone, depth, and tinting, through a carbonization more or less complete, and more or less pronounced, produce extremely varied and remarkable effects in the hands of the artist. The pyro-gravure apparatus, devised by Mr. Perier, consists at present of three principal parts, viz.: an air reservoir, a carbureter, and a thermo-tracer.

The air reservoir consists of an iron plate cylinder, *C* (Fig. 1), which enters an annular receptacle, *A B*, so as to lighten the apparatus. This cylinder, which is lifted in order to fill it with air, contains enough of the latter to last for an hour's work. It suffices, then, to raise it once per hour, an operation that may be performed without much labor. While it is being raised, the air enters through the valve, *E*. The cylinder descends by its own weight and exerts upon the air a pressure that may be made to vary within certain limits by charging the cylinder with weights that vary in heaviness according as it is desired to give the thermo-tracer a more or less elevated temperature.

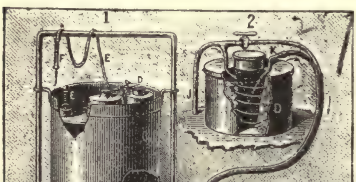


FIG. 1.—Pyro-engraving apparatus.

The air compressed by the cylinder escapes through the tube, *J* (Fig. 1, No. 2), and divides into two parts. One of these enters the carbureter, *D* (which consists of a vessel containing a sponge saturated with a hydro-carburet—alcohol, wood, naphtha, benzine, etc.), makes its exit at *K*, and reaches the thermo-tracer through a very flexible rubber tube. The other portion of the air flows directly to the tracer, in order to keep its handle cool. To this effect the thermo-tracer is provided with a hollow wooden handle, around which circulates the air forced directly by the reservoir, aud the discharge of which is regulated by a cock situated above the carbureter, so as to prevent waste, and yet at the same time to assure sufficient cooling. The thermo-tracer is a simple metallic tube, to which is screwed the platinum tube, *H*, raised to incandescence. The enlarged part contains an aperture through which escape the products of combustion, which latter takes place at the pointed extremity of the platinum tube.

Tracers of varying sizes and contours can be screwed on, according to the nature of the work to be done, and the effects produced may thus be varied.

QUARRYING MACHINERY. The most important improvement in quarrying appliances made within the decade is the general adoption of the channeling process, which has been rendered possible by the improvements made in channeling machines. The channeling process is a means by which artificial seams are made in the quarry for the purpose of releasing masses of stone. An intelligent and proper use of the channeling process does not involve the cutting up of stone in blocks as ice is harvested, but its use is to release a large mass or bed in such a way that by the action of plugs and feathers, wedges, or by blasting, the stone may be entirely freed in the quarry. It is only while cutting out the key block that all four sides of a block of stone are channeled. If there is a free bed on the bottom—that is, if the stone is laid in layers deposited one upon the other—it is simply necessary to channel around the walls of the quarry, because by means of the plug-and-feather process, or by blasting, the blocks of stone may be sheared on the bed. Where there are no free beds the channels are cut around the walls and directly across the quarry in parallel rows.

The Wardwell Channeler, illustrated and described under "Quarrying Machinery," Vol. II. of this work, having come into extensive use, is manufactured in at least half a dozen different factories in different sections of the United States. The general design and construction have not materially changed, the improvements which have been made being only matters of detail.

The Bryant Channeler, Fig. 1, is constructed on the basis of the Wardwell machine, but differs in the method by which the work is accomplished, and contains several useful improvements. The principle is differently applied from the Wardwell, for while the side arms of the Wardwell are bifurcated, or forked, working with one rubber between the forks and one on top, with stirrups to shackle them together, in this machine the lever consists of two arms opposing each other, working on a common fulcrum, with rubbers or steam cushions on both sides of fulcrum working freely, without stirrups. The cups holding the rubbers may be moved at more or less distance from the fulcrum, thus admitting close adjustment to the elastic condition of the rubber or variation of the blow. The levers are hung on a movable fulcrum, being placed in a hanger, which may be raised or lowered by means of a screw, and retained in position by guides which are bolted to the frame. This admits of the feeding of drills down as the cutting proceeds, and also of the dropping of levers, without the compression on the rubbers. When both gangs are running on a 60 or 100-ft. run, the operator is enabled to keep the machine in continuous motion until he has sunk 15 or 20 in. The guides for the clamp as arranged for limestone are similar to those used in the Wardwell, with the exception that they are continuous from bottom to top and admit the drills being brought down till the top clamp touches the bottom clamp. The propelling end of the lever is operated from the main shaft by a disk connected by a sliding box and movable wrist-plate. This changeable wrist-plate admits a change of stroke from 4 to 8 in., and may be placed on the center when it is only wanted to operate one side. The propelling gear is operated by a reverse-motion friction clutch on the crank shaft geared to a shaft that connects with both sets of trucks by worms and worm gears. This arrangement holds the machine at any point when working on a slope. The friction clutch is not so positive as to force the machine against an obstruction, but will slip when the pressure comes too hard on it. It will work on an incline of 1 ft. in 10 with safety. Where the incline is too steep, a drum on one of the axle-trees is used of the same size as the tread of the wheel, with a wire rope attached to it, and made fast to a plug at the upper end of the cut. This is wound upon the spool going up, and unwound coming down, making a positive feed. Four cutters are used in a gang of drills in sandstone. The two outside drills are chisel-shaped points, cutting at right angles with the channel. The two inside drills cut diagonally across the channel. The speed on the track is three-quarters of an inch at every stroke, and may be 200 revolutions with both sides working all the time. With the four drills the bottom of the channel is kept smooth and free from "frogs." The frame is constructed of channel steel and steel I-beams, bracketed together with malleable iron brackets and boiler rivets.

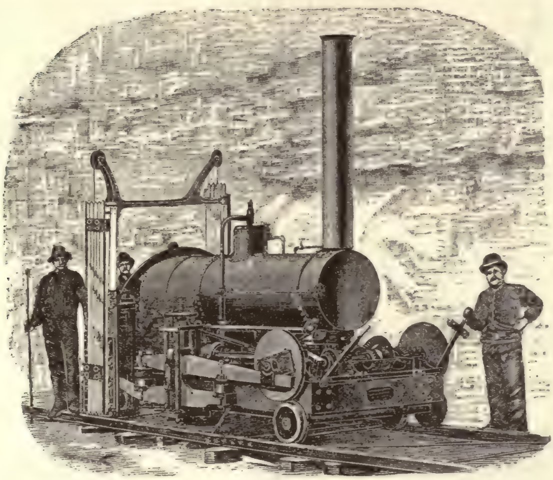


FIG. 1.—The Bryant channeler.

Some recent improvements have been made in the Bryant channeler, notably a sliding

box for holding the gibs, and which admits of their being dropped into a pocket so that the arm holds them in their place, and if they break they cannot get out of place. The old method was to hold the gib in the box by an enlarged head, which was liable to break, resulting in the dropping of the gib into the cut. By means of the improved gib box on the Bryant channeler it has been found advantageous to use gibs made of hard wood. These have proved to be much better and more durable than brass. The wooden gibs absorb the oil and make but little noise; they wear as long, and cost very much less than brass. The importance of the wooden gib is shown by the fact that the Cleveland Stone Co., at Cleveland, Ohio, which has a large number of channeling machines in use, using brass gibs, pay about $600 per year for gibs. Another improvement is a steam cushion instead of a rubber one. For this purpose a 6-in. cylinder 5½ in. long is used. Steam is admitted from the boiler, through a small opening into the cylinder. This forces the piston out to the mouth of the cylinder, where it is held by lugs from going further. When the pressure comes on the piston, it forces the steam back into the boiler, but the pressure comes so quickly, and the opening is so small, that but little escapes.

The Saunders Direct-acting Channeling Machine, designed by the writer, is shown in Fig. 2. Steam is supplied through hose, and a back screw is arranged so that the engine

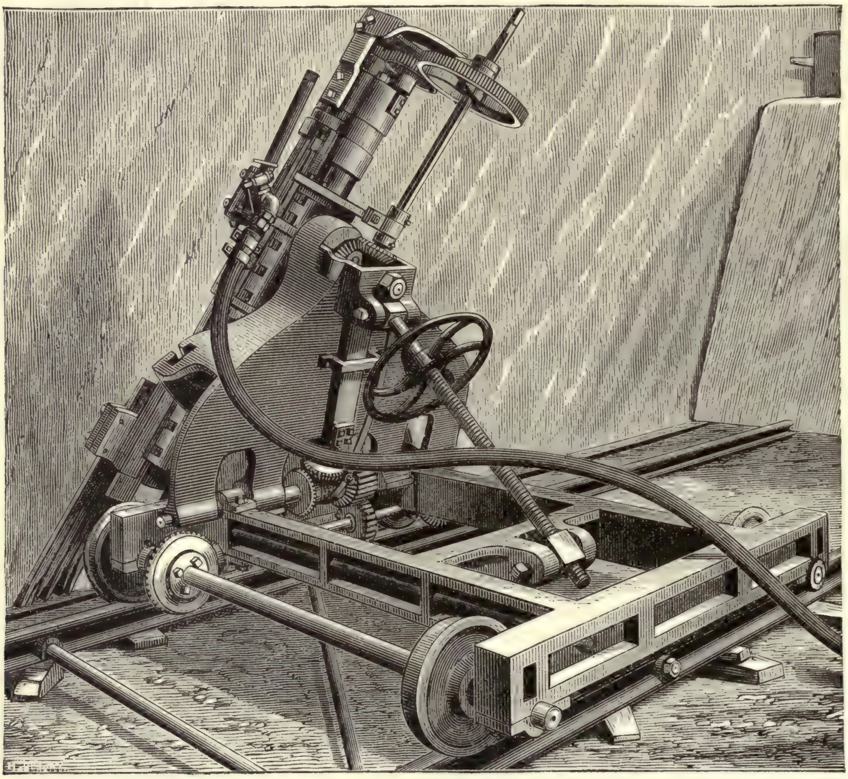


FIG. 2.—The Saunders channeling machine.

and cutting tools may be tipped backward for use in what is known as "side-hill work." A standard Ingersoll "Eclipse" rock drill of large size, 6 in. diameter of cylinder, is used, the machine being specially constructed for channeling purposes. Instead of a regular rubber buffer in the front head a dozen or more plate washers are used. The piston-rod carries a cross-head to which are attached a gang of cutting tools. The whole is mounted in a vertical position upon an adjustable cast-iron support known as a quadrant piece, which rests upon a shaft bearing upon a carriage, which moves upon four wheels. The cutting engine is mounted on a shell piece in a similar manner as rock drills are mounted, and is fed forward as the cutting progresses. This shell piece serves also as a guide for the cross-head, thus preventing the channeling bits from turning.

The distinguishing features of this machine are that it is direct acting; that is, the cutting tools being attached rigidly to the piston, the blow is dealt directly by the steam pressure in the cylinder and without any intervention of crank shafts, levers, or springs. The feed motion of the carriage upon the track is operated by, and dependent upon, the engine which strikes the blow. The piston in its upward stroke is made to rotate a pawl piece at the top of the cylinder, and this rotation is conveyed through gears to the axles of

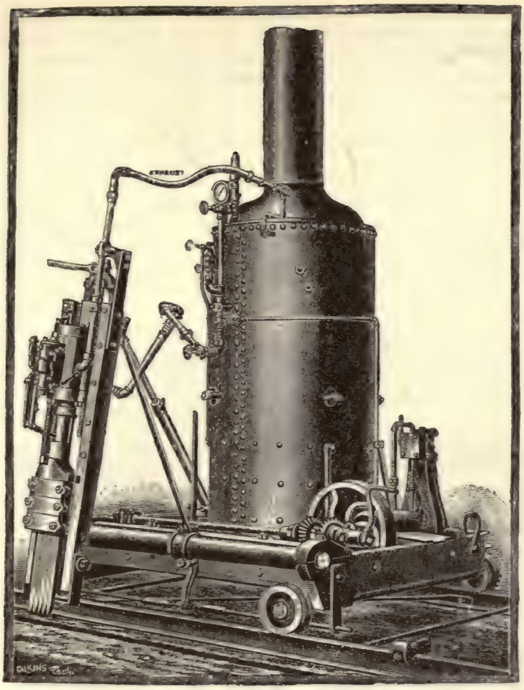


FIG. 3.—Sullivan channeling machine.

the car, and it is thus fed through traction upon the rails. This feed motion is imparted to the car on the upward stroke of the piston only ; the car remains stationary when the blow is struck. There is thus an intermittent feed motion, and the drills are moved a definite distance in the cut at every stroke, thus chipping its channel and not powdering it, as is the case with other machines. This feed averages three-quarters of an inch per stroke. The strokes average 240 per minute. The cutting tools are made adjustable to any angle, to the right and left, and forward and backward. The machine is thus capable of making transverse and side-hill cuts, and does what is known as cutting out the corners in quarrying. The machine has but two quick moving parts: the piston, with cutting tools attached, and the valve. The stroke varies about 6 in. in length, running from 2 to 8 in. This is done by the peculiar construction of the piston and valve. The engine and cutting tools are fed downward as the cutting proceeds, and the drills can cut a channel 18 in. in depth without unclamping or stopping the machine. By a stop-valve placed in the lower steam-port the blow can be regulated so that it will strike with only a light touch, or with a blow of 3,000 lbs. in force.

The Sullivan Channeling Machine.—Fig. 3 illustrates the Sullivan channeler with boiler mounted. This is also a direct-acting machine, having no levers or springs, and the cutting tools are attached rigidly to the piston-rod of the engine. This channeler is also made on the screw-frame pattern without boiler, the steam being supplied from a stationary boiler through flexible tubing. An independent engine is used to feed the carriage along the track ; thus the engine that does the cutting is not used for the feeding. The feed engine is a common upright engine of New York safety steam-power pattern. It revolves a shaft on the end of which is a gear which is used to rotate the axles of

FIG. 4.—The Wardwell channeling machine.

the carriage. The engine which carries the cutting tools has a valve movement which is operated by bell-crank levers connected with the cross-head. The cutting tools abut against the cross-head, and are clamped by three separate clamps. Piping and swivel joints are used in place of steam hose. The movement of the carriage is reversed either by a hand lever or by an automatic adjustment suspended under the car, which bears against an abutment bolted to the rail.

The Wardwell Side-hill Channeling Machine, made by the Steam Stone Cutter Co., of Rutland, Vt., is represented in Fig. 4. This is a single-gang machine of the Wardwell pattern, and is shown mounted on its track on the bed of the quarry. It is adapted for cutting either vertical or inclined channels. By its use quarries can be enlarged by carrying under the wall channels, or, if the strata or vein of rock is inclined, channels can be cut to follow the inclination to any angle down to 45°. The operating mechanism and cutting devices are mounted upon a portable sliding carriage, and, by means of a long screw shaft, can be readily adjusted at either end of the frame—thus making a right or left-handed machine—thereby enabling it to cut in all corners of a quarry. The engine is attached to the standard that gives direction to the gang of cutters, and motion is communicated to the cutter by means of two levers, the upper ends of which are pivoted to the cross-head of the engine, and their lower ends are connected by links to the lower clamp block which holds the cutters.

The Saunders Bar Channeler, designed by the writer, and manufactured by the Ingersoll-Sergeant Rock Drill Co., is represented in Figs. 5 and 6. The distinctive difference between this machine and others is that no track is used, but the engine carrying the cutting tools is fed back and forth upon bars which rest upon end supports. It is a combined rock drill, quarry bar, and channeling machine, and will do both drilling and channeling. As a channeler it does not cut by putting in holes and broaching the partitions between them, but makes a continuous channel, moving in the direction of the cut while striking, this movement being automatic; but instead of moving on a track it moves upon parallel bars.

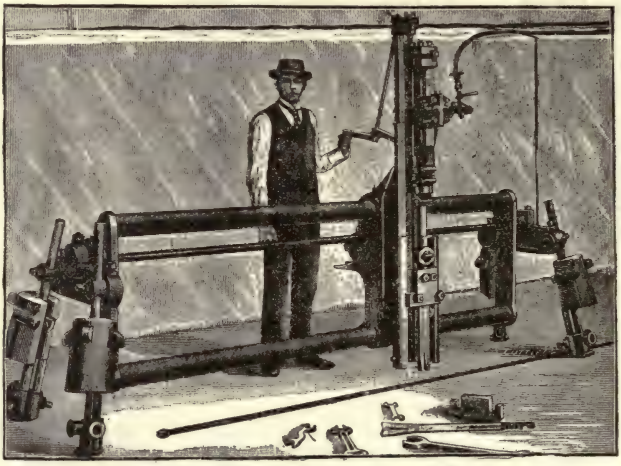


FIG. 5.—Saunders bar channeler. Vertical.

The chisels or cutters are of the regular pattern with the diagonal bit, and the speed of the machine is equal to the piston speed of a regular rock drill of the same size when used to put in a hole; hence its great cutting capacity. The cutters are directly under the center of the piston-rod, and are separated from the piston by a dowel shank of less diameter than the piston-rod, which prevents breakage of the piston-rod.

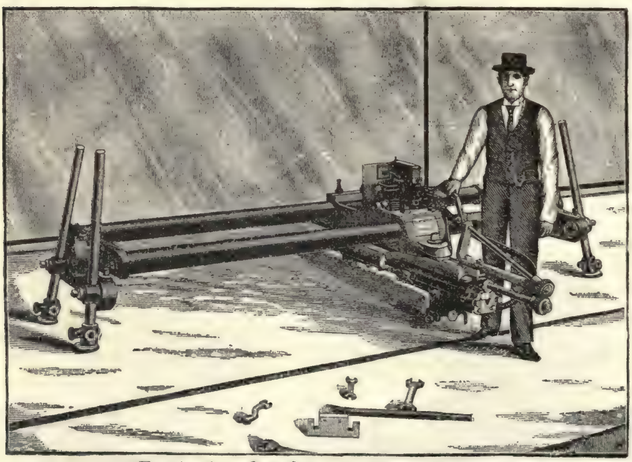


FIG. 6.—Saunders bar channeler. Horizontal.

The machine puts in a round hole at each end of the bar, thus forming the limits of the channel to be cut. After this is done, by a very simple and quick change, the channeling bits are attached and are reciprocated automatically between these holes. The importance

of these holes will readily be seen in that they complete the channel to the full depth at the bottom, without what is usually known as "running off," and without requiring any hand labor at the end of the cut. After the channel is completed to the full depth, and for the full length of the bar (which is about 10 ft.), the whole machine is barred along ten feet further and one hole is put in, the channel being continued up to this hole. The movement of the bar is very much facilitated by shoes fastened on each leg. The legs are adjustable so as to take all angles and to adapt themselves to any irregularity of the surface of the quarry. The machine is shown doing vertical channeling in Fig. 5, and by revolving 90° may be applied to do horizontal channeling, in Fig. 6. Horizontal channeling is confined to work where vertical channeling is not sufficient to remove the blocks. It is obviously more expensive to cut a channel horizontally than to cut it vertically, because in vertical channeling we have the benefit of the weight and inertia of the cutting tools.

In adapting the bar channeler to the making of channels upon inclined floors, a counterweight is employed, which hangs over a pulley at the top of an upright piece which is fixed to the end of the machine. It serves to enable the feeding engine to carry the cutting tools up and down hill while at work. This machine is used to channel slate, several of them being at work in the slate quarries near Bangor, Pa. Their cutting capacity in slate is from 75 to 150 sq. ft. of channel per day.

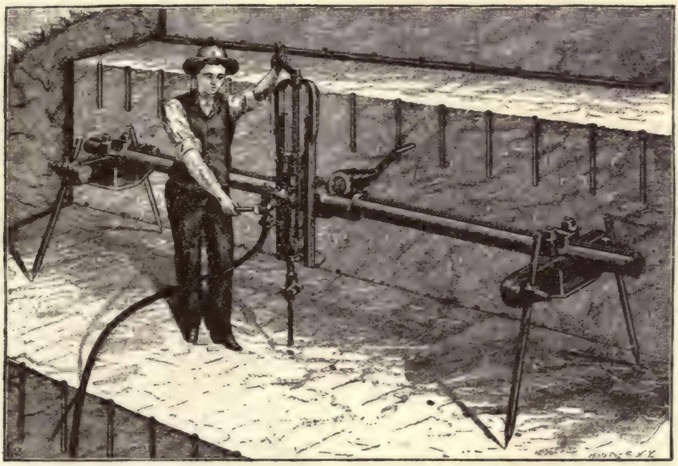


FIG. 7.—Plug-and-feather bar. Vertical.

Figs. 7 and 8 illustrate the form of quarry bar largely used in quarries for the purpose of drilling a line of holes for plug-and-feather work. This bar is also used to a limited extent for drilling holes for blasting purposes. Several forms of bars are in use, some of them being made of angle iron, but the simplest is that shown in the cut, which is made of a piece of extra heavy wrought-iron pipe, turned in a lathe and provided with a rack riveted to it running longitudinally. The bar is mounted upon end pieces, which are in turn provided with swivel connections in which are inserted four legs or supports. These legs are adjustable in length and in angle, so that the bar may be placed on irregular floors. A rock drill is mounted upon the bar with a carriage which is provided with a pinion and crank. The operator by turning the crank moves the drill to any point along the bar.

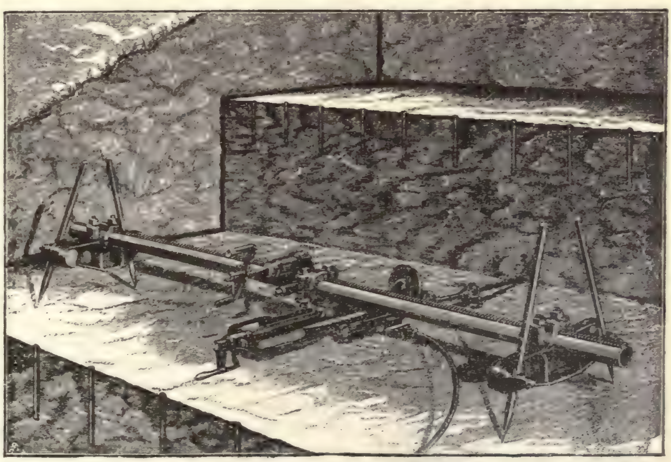


FIG. 8.—Plug-and-feather bar. Horizontal.

In quarries and in stone-yards it is frequently noticed that a number of men are employed to drill small holes, from 3 to 6 in. deep, in large blocks, for the purpose of splitting up the blocks into sizes for the market. In granite, a great deal of this work is done by hand. This can be done by machinery about ten times as fast, and at much less expense.

A small drill is mounted on a light weight-bar, the whole resting upon two large blocks of stone, thus making a gallows over a section of track. A truck of home-made construction, with perforated wheels, carries the block of stone and moves under the gallows. The wheels are so perforated that a quarter turn with a crowbar moves the truck just far enough to separate one hole from the other. This is usually about 6 in. The operation is very simple, two men only being required, one to run the drill and the other to move the truck. It is simply necessary to turn on the steam, drill a hole, wind the steel out of the hole, moving the truck, and so on until the entire line of holes is drilled. The drill is then moved along the bar and another line of holes is put in. In granite, these machines have recorded holes 3 or 4 in. deep in three-quarters of a minute each. It is moved and started in another hole in less time. It will put in about 100 lineal ft. of hole in a day, and will do the work of about ten men. Two drills may be used on one bar. The bar may be mounted on upright wooden frames instead of on legs, thus giving a lateral movement and a larger drilling area.

In broach channeling, a line of holes is driven, leaving a dividing wall of about three-quarters of an inch between the holes. When these holes are completed to the depth and extent required, the rotation pawls are released, and the drill is made to break down the dividing walls by means of a broach, and without rotating the piston.

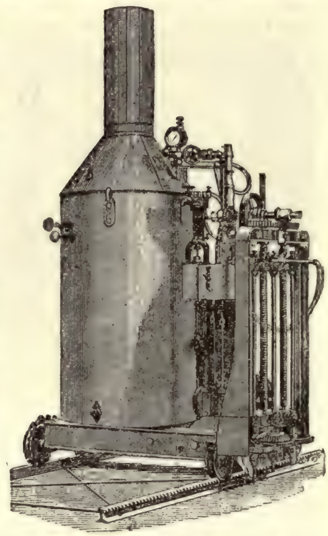


Fig. 9.—Diamond channeler.

The Diamond Channeling Machine is represented in Fig. 9. This is the only machine used for stone channeling other than the percussive machines hereinbefore described. In some cases no boiler is placed on the machine, thus enabling the drill spindle to be tipped backward. Diamond channeling machines have been largely used in the Vermont Marble Quarries, where progress has been made to a depth of 400 ft., following a vein under the hill. Their extreme adaptability to any angle, and the fact that the carriage does not move on the track while the machine is working, gives it a special value in angular quarries and places where the floor is not level or regular. The track upon which the machine is mounted is made of a special rail, on one side of which is a rack; the car moves in this rack through a pinion, and by means of a hand crank the machine is moved a definite distance after each hole. Holes are drilled on the line of the proposed channel in the same manner as diamond drills are operated. A stationary engine revolves a spindle on the end of which is a diamond bit. This bit differs from that used for prospecting in that it is solid instead of cored out, so that it bores the hole and discharges the cuttings to the full diameter of the hole. The bits are usually about 1¾-in. in diameter, and the holes are drilled close together, leaving a slight space between, which is afterwards bored out by the same bit through a guide piece which follows in an adjacent hole.

Fig. 10 illustrates a special tripod carrying a drill for putting in lewis-holes. This tripod is of the regular pattern, except the center bar, which carries the drill, is extended in length, and is perforated with a slot 7¼ in. long, which allows the drill clamp to move 6 in., to cover the centers of three parallel holes, 3 in. each, center to center. When the three holes are finished, a broach is inserted in place of the drill without moving the tripod, and the lewis-hole finished by broaching down the partitions. This obviates the difficulty of breaking down the partitions in the old plan of diverging holes, as shown in the right side of Fig. 11.

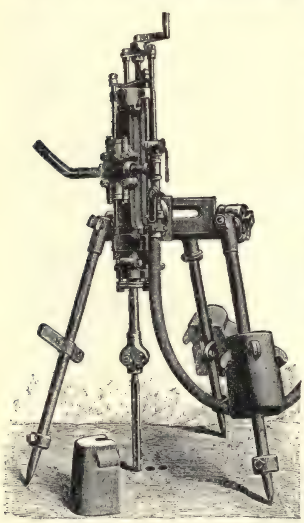


Fig. 10.—Tripod drill.

Gadding Machines.—A quarry gadder is a machine by which holes are inserted into the side of the bench for the insertion of plugs and feathers, by means of which the blocks are separated in the quarry. Fig. 12 illustrates a gadding machine, designed by the writer of this paper, and made by the Ingersoll-Sergeant Drill Co. This machine is used for putting a series of holes on a true line in stone, for the insertion of plugs and feathers for breaking up the blocks. It is used in connection with the channeling machine in what is called "lofting," or breaking from the floor of the quarry into the cut made behind, and for breaking the stone in sections by a series of horizontal holes driven into the side of the

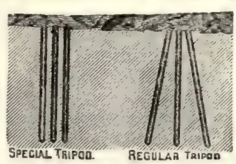


Fig. 11.

bench. In marble quarries, where it is desired to separate the "stock," these holes are placed on the line of the "riving bed." or with the dip of the marble. The machine consists of the improved Ingersoll "Eclipse" rock drill, mounted upon and made to traverse longitudinally a standard or post, which is fixed through trunnions at its lower end to a cast-iron bed-piece or car, and which is made to swing in a vertical plane from a perpendicular position to a nearly horizontal one. The drill is pivoted to a saddle, which is raised or lowered on the standard by means of a chain, which passes over a pulley at the top and around a shaft, which is turned by a crank. The saddle is fixed at any desired point on the standard by means of a taper gib, which is tightened or loosened by the throwing up or down of a handle in the side of the saddle. The car moves along the floor, without a track, and is fixed in position by means of corner pins, which are driven into the floor and set by set-screws. The machine will put in holes close to the bottom of the quarry, in a horizontal position along the bench, into the roof, or perpendicularly into the floor, as desired. These varied positions are effected by swinging the drill on its pivot with the saddle, and by adjustment of the standard. Where it is desired to use water in the holes during the drilling, a tank is placed on the bench, in a position about 6 ft. above the drill, and through a small hose water is siphoned into a nozzled pipe, which is fixed to the shell, and which points to the hole, remaining in a fixed position, with the nozzle a few inches from the orifice. Where the bench is 6 ft. or more in height, it is best to use a tie-rod or brace while putting in the top holes. This rod is attached to the upper part of the standard at one end, and is driven into the cut beyond the bench at the other, and will thus resist the thrust of the drill. The record of this machine in marble is 300 lineal ft. of 2-ft. holes in a day of ten hours. It requires twenty seconds to remove from a 2-ft. hole and place the drill in position to begin another. The machine will put in a hole 3 ft. in depth without stopping.

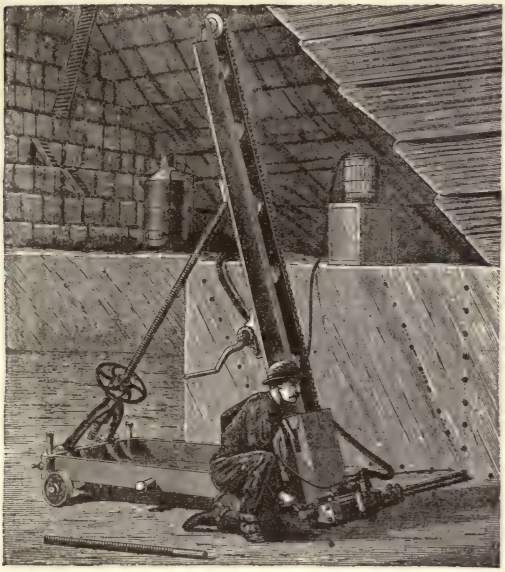


FIG. 12.—Gadding machine.

The Diamond Gadding Machine is represented in Fig. 13. The machine is placed upon a platform on trucks arranged to run upon a track. When adjusted for work it may be braced by the pointed legs shown. The boring apparatus is attached by a swivel to a perpendicular guide-bar. This guide-bar is secured to the boiler behind it, which forms the main support of the machine. Upon the guide-bar the boring apparatus may be raised or lowered at pleasure, for the purpose of boring a series of holes in a perpendicular line if desired. Upon the swivel the boring apparatus may be turned, so as to bore in any direction within the plane of the swivel-plate. The illustration shows the drill-rod or spindle placed near the base of the machine, and so as to bore horizontally. At one end of the spindle is the drill-head, armed with carbons, and supplied with small apertures or outlets for water. At the other end of the spindle is attached a hose for supplying water to the drill-head. A rapid revolving movement is communicated to the drill-spindle by the gears shown. The speed and feed movement may be regulated by the operator with reference to the hardness or softness, coarseness or fineness, of the material to be bored; and the feed movement may be instantly reversed at pleasure.

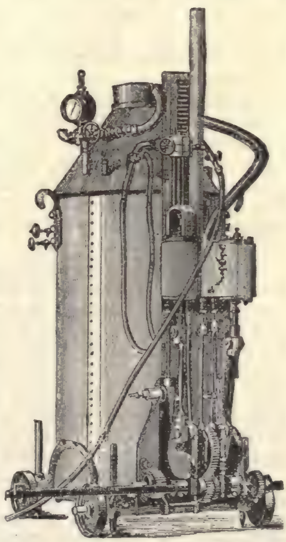


FIG. 13.—Diamond gadding machine.

Channeling-machine Bits.—All percussive channeling machines carry a gang of cutters bolted together, and in every case the bits or points are chisel-shaped, some of them having straight edges and others diagonal ones. The cutting tools are in the shape of gangs, instead of being in solid bars, because they are more readily handled and transported to the blacksmith shop, and because the breakage of a bit is adjusted

by replacing only one bar in the gang. A 3-drill gang is used with the bar channeler, and sometimes with the track channelers in sandstone, or very soft material. The 5-drill gang is used with track channelers. The bits of the gang for channeling differ somewhat according to the stone. For marble and limestone the points taper sharply, as shown in the figures. In sandstone the points are more blunt, with heavy edges, so as to prevent wear of gauge. It is also advisable in some kinds of sandstone to curve the cutting edge of the bit—that is, to make it convex, and thus prevent wearing of the gauge to a taper and "sticking." Sticking is a troublesome feature in sandstone quarries, because the bit wears away the gauge rapidly. The object of the diagonal bit is to maintain a level bottom to the channel. Without it the channel would be "rutted." The edge of the diagonal bit cuts away what is known as the "frog." This frog is formed by glancing of the straight bit, it not being perfectly rigid, especially in deep cuts. The edge of the diagonal bit strikes the frog diagonally across the top, and thus cuts it away. In very deep channels it is sometimes advisable to use an extra clamp down in the cut, or above it, directly under the cross-head, in order to prevent springing of the bars.

Steel gang channeling machines, cut in marble from 75 to 125 sq. ft. of channel per day of 10 hours ; in oölitic limestone and in sandstone from 150 to 400 sq. ft. In marble channeling is done at from 10 to 25 cents per sq. ft., equivalent to from 3 to 5 cents per cub. ft. of stone quarried. In oölitic limestone and sandstone the cost is about one-half these figures.

The Plug-and-Feather Process is distinctly an American invention, the old system being a trench in the stone with a wedge for splitting. There are many advantages in the plugs and feathers over wedges. Less stone is wasted, because the plug-and-feather process requires only a hole of small diameter while the wedge process involves a trench several inches wide at the top. The plug is a common piece of steel, wedge-shaped. The feathers are made of half-round iron, drawn down to a point which is bent over. When the hole has been drilled to the required depth, the feathers are first inserted, then the plug is driven down between them; thus a tension is exerted on the walls of the hole for the full depth of the feathers. It is obviously important in breaking up a block of stone that the break be true. With the wedge process the force is exerted only at the top, hence the stone is apt to break irregularly, while with the plugs and feathers holes are drilled sometimes to the full depth of the stone, and the plugs and feathers inserted for almost the full depth of the hole ; thus a straight and true break is made. The plug-and-feather process has followed the use of rock drills on quarry bars. Until recent years the wedge process was used in the Ohio sandstone quarries, and almost universally in Europe, but plugs and feathers have been adopted in progressive quarries.

Quarrying by Wire Cord.—This method is exclusively employed at two marble quarries in Belgium, and is also in use for quarrying various descriptions of stone, including granite, in several countries of Europe, as well as in Algeria and Tunis, not only subdividing blocks, but also sawing large masses out of the solid rock. For this purpose a cord, barely ¼ in. in diameter, composed of three mild steel wires, is made to travel at about 13 ft. per second, while the diameter is reduced and the speed slightly increased as the length of cut decreases for subdivision of the blocks. The twist of the cord causes it, while running, to turn upon itself, thus becoming worn evenly over its whole surface, so that eventually it presents the appearance of a single wire, but little larger than those which originally composed the cord. It is then incapable of carrying along the sand and water, but may still be used for fencing and a variety of purposes. Before being worn out, however, a cord 150 yds. long is capable of cutting to a depth of nearly 70 ft. in 15 blocks, or of producing about 500 sq. ft. of sawn surface in marble. In a block of marble 15 ft. long the rate of the cut is 14 in. per hour, and in granite about 1 in. One endless cord, guided by grooved pulleys, may be made to cut at several different places, provided they be not too close together ; and, as there is so little surface in contact, a very small amount of motive power is required to drive. The tension is maintained by a weighted truck on the incline, and the feed is given by an endless screw, rotated automatically in stone of uniform texture, or by hand when irregularities are anticipated.

The Knox System of Blasting in Quarries.—The purpose of the Knox system is to release dimension stone from its place in the bed by so directing an explosive force that it is made to cleave the rock in a prescribed line, and without injury. The system is also used for breaking up detached blocks of stone into smaller sizes. A round hole is first drilled—Fig. 14. A reamer, shown in end view in Fig. 14, and in elevation, Fig. 15, is inserted in the hole in the line of the proposed fracture, and made to cut two V-shaped grooves, *A*, *B*.

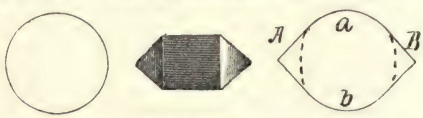


Fig. 14.—Details of Knox system. Reamer.

Fig. 16 is a section of the drill hole. The charge of powder is shown at *C*, the air space at *B*, and the tamping at *A*.

Let us assume that we have a blue-stone quarry in which we may illustrate the simplest application of the Knox system. The sheet of stone which we wish to shear from place has a bed running longitudinally at a depth of, say, 10 ft. One face is front, and a natural seam divides the bed at each end at the walls of the quarry. We now have a block of stone, say 50 ft. long, with all of its faces free, except one—that opposite and corresponding with the bench. One or more Knox holes are put in of such depth and distance apart, and from the

bench, as may be regulated by the thickness, strength, and character of the rock. No man is so good a judge of this as the quarry foreman, who has used and studied the effect of the Knox system in his quarry. Great care should be taken to drill the holes round and in a straight line. In sandstone of medium hardness these holes may be situated 10 ft., 12 ft., or 15 ft. apart. If the bed is a tight one—that is, where it is not entirely free at the bottom—the hole should be run entirely through the sheet and to the bed, but with an open free bed holes of less depth will suffice.

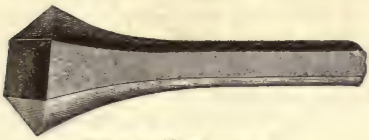


FIG. 15.—Knox reamer.

The reamer should now be used and driven by hand. Several devices have been applied to rock drills for reaming the hole by machinery while drilling—that is, efforts have been made to combine the drill and the reamer. Such efforts have met with only partial success. The perfect alignment of the reamer is so important that where power is used this point is apt to be neglected. It is also a well-known fact that the process of reaming by hand is not a difficult or a slow one. The drilling of the hole requires the greatest amount of work. After this has been done it is a simple matter to cut the V-shaped grooves. The reamer should be applied at the center of the hole—that is, the grooves should be cut on the axis or full diameter of the hole. The gauge of the reamer should be at least $1\frac{1}{2}$ times the diameter of the hole. While driving the reamer great care should be taken that it does not twist, as the break may thereby be deflected. Ream until you can do so no further—that is, ream to the full depth of the hole. The hole is now ready for charging. First insert the powder, which should be a low grade of explosive. Do not use dynamite. Black powder, Judson powder, or other explosives which act slowly, are preferable. No definite rule can be laid down as to the amount of powder to be used, but it is well to bear in mind that as little powder should be used as possible. The powder must, of course, be provided with a fuse. or, preferably, a fulminating cap. It is well to insert the cap about the middle of the cartridge.

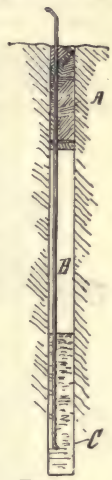


FIG. 16.—Drill hole.

After the charge the usual thing to do is to insert tamping, but in the Knox hole the tamping should not be put directly upon the powder, but an air space should be left, as shown at *B*, Fig. 16. The best way to tamp, leaving an air space, is, first to insert a wad, which may be of oakum, hay, grass, paper, or other similar material. The tamping should be placed from 6 to 12 in. below the mouth of the hole. In some kinds of stone a less distance will suffice, and it is well to bear in mind that as much air space as practicable should intervene between the explosive and the tamping. Care should be observed in tamping not to destroy the wires which connect with the explosive, but the tamping should be made secure so that it will not blow out. The hole is now ready for blasting. If several holes are used on a line they should be connected in series and blasted simultaneously. The effect of the blast is to make a vertical seam connecting the holes, and the entire mass of rock is sheared several inches or more.

The philosophy of the Knox blast is simple, though a matter of some dispute. Mr. Knox gives the following explanation :

"The two surfaces, *a* and *b*, Fig. 14, being of equal area, must receive an equal amount of the force generated by the conversion of the explosive into gas. These surfaces being smooth, and presenting no angle between the points, *A* and *B*, furnish no starting point for a fracture, but at these points the lines meet at a sharp angle, including between them a wedge-shaped space. The gas acting equally in all directions from the center is forced into the two opposite wedge-shaped spaces, and the impact being instantaneous, the effect is precisely similar to that of two solid wedges driven from the center by a force equally prompt and energetic. All rocks possess the property of elasticity in a greater or less degree, and this principle being excited to the point of rupture at the points *A* and *B*, the gas enters the crack and the rock is split in a straight line, simply because under the circumstances it cannot split any other way."

It is doubtless true that, notwithstanding the greater area of pressure in a Knox hole, the break would not invariably follow the prescribed line but for the V-shaped groove, which virtually starts it. A bolt, when strained, will break in the thread, whether this be the smallest section or not, because the thread is a starting point for the break. A rod of glass is broken with a slight jar, provided a groove has been filed in its surface. Numerous other instances might be cited to prove the value of the groove. Elasticity in rock is a pronounced feature, which varies to a greater or less extent, but it is always more or less present. A sandstone has recently been found which possesses the property of elasticity to such an extent that it may be bent like a piece of steel. When a blast is made in the Knox hole the stone is under high tension, and, being elastic, it will naturally pull apart on such lines of weakness as grooves, especially when they are made, as is usually the case in the Knox system, in a direction at right angles with the lines of least resistance.

Our previous illustration of a break by the Knox system was its simplest and best application. An identical case would be one where a large and loose block of stone was split up into smaller ones by one or more Knox holes. But those who use this system do not confine it to such cases alone. Horizontal holes are frequently put in, and artificial beds made by

"lofting." In such cases, where the rock has a "rift" parallel with the bed, one hole about half way through is sufficient for a block about 15 ft. square, but in "liver" rock the holes must be drilled nearly through the block, and the size of the block first reduced. A more difficult application of the Knox system, and one requiring greater care in its successful use, is where the block of stone is situated as in the case hereinbefore cited, except that both ends are not free, one of them being solidly fixed in the quarry wall. A simple illustration of a case of this kind is a stone step on a stairway which leads up and along a wall. Each step has one end fixed to the wall and the other free. Each step is also free on top, on the bottom, and on the face, but fixed at the back. We now put a Knox hole in the corner, at the junction of the step and the wall. The shape of the Knox hole is as shown in Fig. 17.

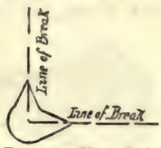


FIG. 17.—Knox hole.

It is here seen that the grooves are at right angles with each other, and the block of stone is sheared by a break made opposite the bench, as in the previous case, and an additional break made at right angles, and at the fixed end of the block. Sometimes a corner break is made by putting in two of the regular straight Knox holes in the lines of the proposed break, and without the use of the corner hole.

RAILROAD, CABLE. The wire-cable system of street railways was first put into use in San Francisco, Cal., in 1873, when the Clay Street Hill Railroad was constructed in accordance with the plans of Mr. Andrew S. Hallidie. Practical employment has proved that the system possesses, among others, advantages which may be summarized as follows: The steepest grades are as easily worked as levels; the cars may be stopped instantly at any point on the line, and started with promptness and ease; the speed is uniform, and any rate may be established that is desired; the method of working is noiseless and even; cleanliness of the track is secured; a capacity of increase is obtainable at any time an increased carrying capacity may be required, and there is freedom from snow blockade.

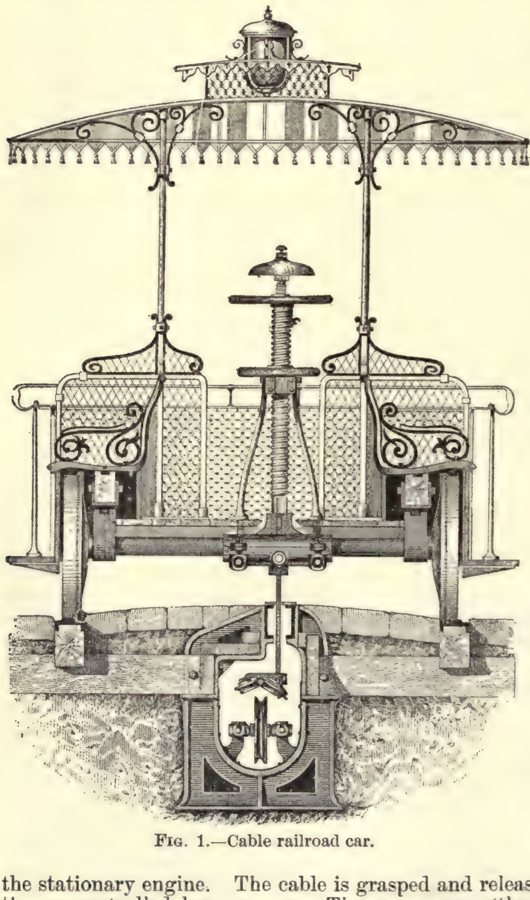


FIG. 1.—Cable railroad car.

The Cable System of the Pacific and National Railway Companies is based upon the patents of Hallidie, Hovey, Paine, Root, and others, and is now employed in San Francisco, Chicago, St. Louis, and many other cities, and also on the East River Bridge, between New York and Brooklyn. It consists simply of an endless wire rope placed in a tube (having a narrow slot from ½ to ¾ in. wide), beneath the surface and between the rails, maintained in its position by means of sheaves, wheels, or rollers. The rope is kept continuously in motion by a stationary steam-engine at either end of the line, or at any convenient point between the two extremes. A gripping attachment at the end of a vertical steel rod connected with the car, and passing through the narrow slot in the tube, transmits the motion of the cable to the car. The speed at which the car moves is determined by the rapidity of the cable, and this is regulated by the revolutions of the driving-wheel at the stationary engine. The cable is grasped and released at pleasure, and the movement of the car controlled by one man. The car or cars (there may be any number used together) start without shock or jar, and are stopped instantly at any point more readily than a horse-car, and hence are less liable to accidents. The system can be adapted to any grade or curvature, even to turning the corner of a street at acute angles of limited radius. A variety of different forms of gripping attachments or "grips" have been devised. The typical variety used on the Clay Street Hill Railroad is illustrated in Figs. 1 and 2. A vertical slide, Fig. 1, works in a shank, and is moved up and down by a screw and hand-wheel. The small upper screw going down through the large hollow screw operates it. At the lower end of

this slide is a wedge-shaped block. The wedge actuates two jaws horizontally, which open and close according to the direction in which the slide is moved, closing when the slide is moved upward. These jaws have pieces of soft cast-iron placed in them, which are easily removed when worn out. These pieces of iron are of proper shape and size inside to grip the rope when they are closed over it. On both sides of these jaws and attached to them are four small pulleys. These pulleys are held by means of rubber cushions, sufficiently in advance of the jaws to keep the rope off from the jaws and at the same time to lead the rope fairly between them, allowing it to travel freely between the jaws when they are separated, without touching them. When it is required to grip the rope, this slide is drawn up by means of the small screw and hand wheel, before described, and the wedge at the lower end closes the jaws over the rope, at the same time forcing back the small guide sheaves onto the rubber cushions. The shank, containing the slide, etc., is enclosed and retained in cast-iron slides attached to the body of the car, and a wrought-iron standard, having a large nut at its upper end, in which the large hollow screw works. The grip is raised and lowered bodily through the opening in the tube from above the surface of the street to the rope in the tube by means of the hand-wheel and nut working on the large hollow screw referred to. The grip is secured to a skeleton or traction-car called a dummy. The dummy is coupled to the passenger cars at the bottom of the incline and uncoupled at the top, and *vice versa*. At first the connection between the dummy and car was made by means of spiral springs, to prevent any jar in starting up ; but this was soon found unnecessary. The arrangements made at the bottom of the incline for keeping the rope at the proper tension and taking up the slack, prevent any noticeable jar in starting. As before stated, the rope is constantly in motion, running between sheaves placed in the tube. The slot of the tube is on one side of a vertical line drawn through the center of the tube ; and referring to Fig. 3 it will be seen that the foot of the gripping attachment projects on one side, giving it an L-shape, enabling the jaws to pass under and over the rope sheaves in tube. In order to stop the car, the jaws of the gripping attachment are slightly opened ; when they release the rope the guide sheaves take it, and the car stops. In another form of grip used on the Sutter Street Railroad, San Francisco, the motion of the gripping jaws is vertical, instead of horizontal, and the rope is taken up and released at the side. In order to run upon or off the rope at the termini of the road, the track and slot diverge from or converge to the line of the rope. Levers are used for operating the jaws instead of the screw.

Fig. 2.—Grip.

The particulars concerning a number of cable roads are given in the table appended to this article. The construction of the Market Street Railroad in San Francisco possesses many points of interest. The foundation for the road-bed and track rests upon concrete piers extending to a depth of 10 ft. or more below the surface of the street. These piers have a width of 5 ft., and are 16 in. thick, and are placed about 9 ft. apart. The track and tube of this road are made into a single rigid structure by connecting the rails and slot-irons by yokes, and uniting the whole by employing concrete. The main tie or yoke connecting the opposite rails is formed of old railroad T-rail, bent in proper shape head down. It embraces the tube, and has fastened to the ends suitable chairs or plates, to which the rails are secured. From the lower part of the curved yoke extend upward two supports for the slot-irons. The lower ends of these are sufficiently separated to form the necessary width for the tube. Tie-rods connect these supports with the main yokes through the chairs. The two rails, slot-irons, and yoke are then all connected rigidly together as one. Car and dummy are united in one vehicle, 34 ft. long over all, and supported on two four-wheel pivoted trucks. The rear truck carries the track-brake, which is between the wheels on each side. In addition there are the usual wheel-brakes. The forward truck carries the grip and hand levers. A rod connects the rock shaft of the track-brakes with the hand lever on the forward truck.

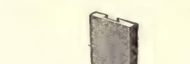


Fig. 3.—Grip.

The grip in use on this road is worked by a lever, and it is formed of two frames, one sliding inside the other. The outer one is secured to the grip-bar on the forward truck by bolts, and carries the lower jaw, while the inner frame, which slides up and down upon the outer one, carries the upper jaw, the quadrant, the operating lever, and adjusting mechanism, and is held in place by guide plates extending across the inside frame, and between which it slides. The frame carrying the jaws passes through the slot directly down alongside the cable without offset. The grip-bar, on which these parts are mounted, is secured and supported by a frame on the running gear or truck, and not on the car itself. The car body therefore can be mounted on springs without any of the spring motion being imparted to the grip, and through it to the cable. In the way in which this grip is arranged all the parts liable to get out of order are accessible, and it is not necessary to provide pits in which to examine them.

When the car is at a standstill the cable passes along over the chilled-iron grooved rollers

at each end of the lower die. The lever operating the grip is then inclined forward. When the gripman desires to start the car, he draws the hand lever back. This action moves the inner frame downward, carrying with it the upper jaw or die. This die consists of a piece of brass secured in the lower end of the sliding part. The lower die is a shorter piece of brass fitted lengthwise between the two rollers. This is arranged with set-screws to be raised to take up wear. The upper die is longer than the lower, and as it is forced down by the inner frame, it rests on the moving cable, and pushes or presses it tight on the rollers before pressing it on the lower die. Gradual motion is thus imparted to the car, without jerk or jar. A still further downward motion of the upper die forces the rope, or cable, onto the lower die, the cable being thus held tightly between the dies. A reverse motion of the lever raises the frame and upper die, and releases the cable, and allows it to run through freely without imparting any motion to the car. The action of the brakes then stops the car.

The heavy traffic and the great length of the cables on these lines have rendered necessary the use of cables $1\frac{1}{4}$ in. in diameter, which are larger than those first used. Their weight is about $2\frac{1}{2}$ lbs. per ft. The rope runs 21 hours per day, at a speed of about 8 miles per hour, the rate of speed for the cars, including stoppages, being about $7\frac{1}{2}$ miles per hour. Every 30 ft. along the road is a grooved supporting pulley, 15 in. in diameter, over the flanges. These pulleys are the rope-carriers. Over each of them is a plate, which may be removed to allow of oiling, etc.

In switching to and from the branch lines, it is necessary to release the cable from the grip while in motion, the car then passing around the curve and switching onto the cable of the other line. In switching from the main to one of the branch lines, in case the cable has not been released by the grip, a safety apparatus, working automatically, closes the switch and compels the car to keep on the main line, when the car is stopped and backed on to the branch line, thus avoiding accident to both grip and cable. At the termini of the various lines, turn-tables 30 ft. in diameter, having two sets of tracks laid thereon, are provided for turning the cars, and are revolved by the power of the moving cable. At the water-front terminus, where the cars of all the lines concentrate, extra tracks are laid converging into the main track, and the cars of the various lines are run upon their respective tracks, as the table rotates. The speed of the table at this point is so increased as to meet the dispatch required. There are three power stations on the lines of this railway. A plan of the main station is given in Fig. 4.

The form of grip used on the Chicago City Railway is illustrated in Fig. 5. The parts of the mechanism are as follows: *A*, grip lever; *B*, lever handle; *C*, lever rod; *D*, lever dog; *E*, lever dog spring; *F*, quadrant; upper *G*, adjusting head; lower *G*, adjusting shoe; *H*, lever set-screw; *I*, adjusting screw; *J*, grip links; *K*, grip beam; *L*, grip shank; *M*, grip plate; *N*, upper jaw; *O*, lower jaw; *P*, spools; *Q*, roller journals; *R*, grip rollers; *S*, cable.

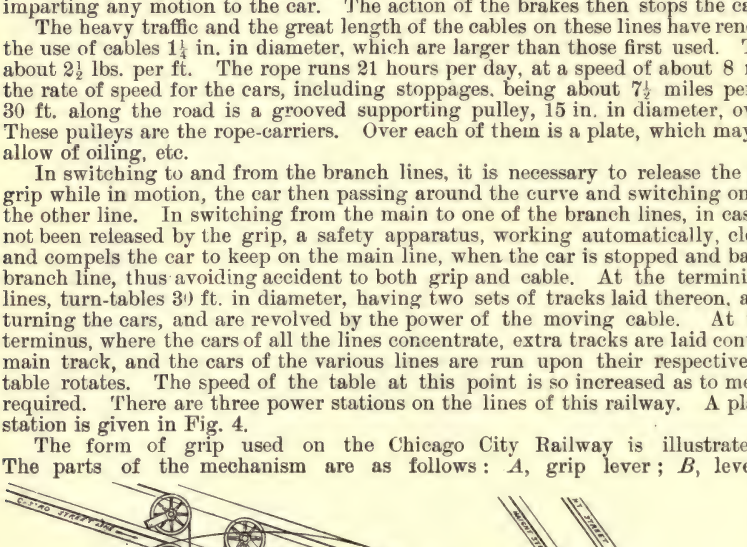


FIG. 4.—Cable railroad.

The Los Angeles Cable Railway is one of the longest in the world, having about 21 miles of single track worked from three power stations. The gauge is 3 ft. 6 in., and the rails, which are of steel, 40 lbs. to the yard, are carried on iron sleepers. The channel in which the cable travels is made of cement concrete, and the slot rails on the top are of steel, and weigh 40 lbs. per yard. The works on this line are of considerable interest, and include three viaducts, while the curves are numerous. One of the viaducts carries the line over the Southern Pacific Railway Co.'s yards. A remarkable feature about it is that the road is supported on single columns, and is believed to be the only instance in existence where two tracks are thus carried, although in certain parts of the elevated railway structure in New York a single track is thus supported. The length of this viaduct is 1,535 ft., of which 50 ft. at each end are occupied by concrete approaches, and the remaining 1,435 ft. represent the length of the metal work. The viaduct affords no thoroughfare except for the cable cars, and in fact no other vehicles could travel over it, as the roadway is all open work. The height from the ground to the rail level is 25 ft. 9 in., and the width between hand rails is 25 ft. The ruling span is 50 ft., but there are two spans of 55 ft., three of 40 ft., one of 30 ft., and one of 20 ft. The main trusses are of the Warren type, 4 ft. deep, and weighing 100 lbs. per running ft. There are two curves on the viaduct, each of 60 ft. radius to the center line, and at these points there are braced posts to take

the strain, and the tracks are also carried on double posts at these points, as well as at the approaches, as a precautionary measure.

The entire length of the straight surface tracks of the cable line is 99,328 ft.; of the viaducts, 4,250 ft.; of bridges, 2,124 ft.; of curves, 2,010 ft.; and of the pits, 562 ft.; making a total of 108,274 ft. of track, or rather over 20½ miles, and the construction required 1,444 tons of track and slot rails, and 2,919 tons of iron sleepers.

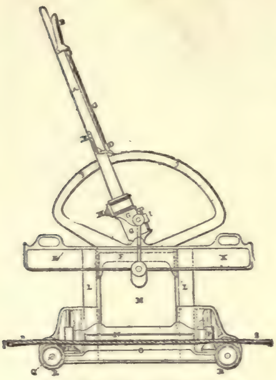


Fig. 5.—Grip.

As already stated, there are three power stations on the system, all similar in arrangement. The engines are compound, the high-pressure cylinder being 26 in. in diameter, and the low-pressure 42 in. in diameter; the stroke is 48 in. They are intended to develop 700 horse-power at a speed of 75 revolutions per minute. The high and low-pressure cylinders are set side by side, and the distance between centers is 10 ft.; the total length of built-up crank shaft is ½ in. over 14 ft. The fly-wheel is 14 ft. in diameter, with rim of 14 in. face by 18 in. deep, and weighs 36,000 lbs. The first driving shaft of the winding machinery is 18 ft. 2½ in. long, with two journals at the ends, and one at the center between the driving rope pulleys. In the bosses of these pulleys the shaft is swelled to 16 in. in diameter. The rope wheels, which are two in number, are 6 ft. 1⅞ in. pitch diameter; they are made in halves and are each grooved for fourteen 2 in. cotton ropes, the power of the engines being transmitted to the driven wheels by a system of endless rope transmission instead of by gearing. The large or driven rope wheels on the main rope shaft are 25 ft. in diameter, built up of ten segments each, with a hollow boss in one piece, and ten hollow arms of elliptical section. The shaft which carries these wheels is 16 ft. 1½ in. long, the diameter in the boss of the wheels being 19½ in. This shaft is coupled at each end to the winding shafts, which are 11 ft. 10¼ in. long, 17 in. in diameter in the center, and 15 in. at the bosses of the overhung rope drums. These latter are mounted on each end of the winding shaft, and each has two grooves for 2-in. cotton ropes, their diameter measured to the center of the rope being 15 ft. They drive two other rope wheels or "idlers," which are mounted on their own shaft. These idlers are of 1 in. less diameter than the driving rope drums, and the purpose of this is always to keep the cotton ropes taut, so that the cable itself may not have to perform any of the work of rotating the idler wheels, the necessary amount of slip required, as these slightly smaller wheels gain on the drivers, being provided for in the clutches with which the cable drums are driven. The cable drums are loose on the extended bosses of the rope wheels, and are held to these wheels by friction disks, which are tightened up by eight screws and hand wheels in each drum. The cable drums on the winding shaft are 13 ft. in diameter, with five grooves each for 1¼ in. cable, and those on the driven shaft are of the same diameter, but with four grooves in each. The cable speed corresponding to 75 revolutions per minute of the engines, is 8½ miles an hour.

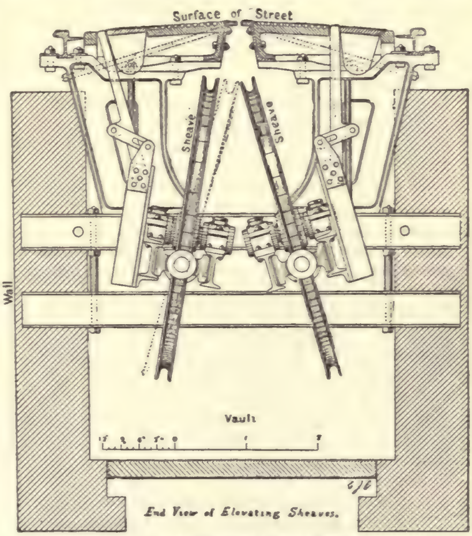


Fig. 6.—Duplicate cable railroad.

The Miller or American System of Cable Railways is constructed by the American Cable Railway Co. of New York, and is based upon the designs of Mr. D. J. Miller. The principal characteristic of this system is the use of duplicate cables laid parallel to one another through the tube on either side of the slot, and so arranged at the driving station that if one cable or its machinery should become disabled, the second rope can be brought into immediate use. Each system is entirely independent of the other by reason of this duplication. The following advantages are claimed: Besides operating the road uninterruptedly, the motive power is more durable, as ample time can be allowed for close inspection and needed repairs, thereby prolonging the life of both cable and machinery. Roads operated by duplicate cables can run steadily twenty-four hours per day, while with but one rope this is not possible, as some time must be devoted to examination and repairs. This system is in use in New York City on the Tenth Avenue road, where the cables are worked independently in the following manner:

At the point where the cable is first carried into the conduit, sheaves 4 ft. in diameter

(called elevating sheaves) are used to elevate the rope to a line where it may be received into the gripper. The sheaves are placed in a frame having trunnions at the ends, on which the wheel tilts. See Fig. 6. This tilting is accomplished by a horizontal lever moving in a vertical plane, and is operated by the grip as the car passes. The normal line of the elevating sheave is in the line of the travel of the grip, and as the car approaches the grip rides on a horizontal lever, which is depressed by the movement and weight of the grip, and in turn tilts the sheave. The grip then passes, the sheave resumes its former position, and the cable is laid between the grip jaws. The cable having been thus received into the gripper at the starting point, is carried to the end of the line, passing freely through the grip jaws in bringing cars to a standstill.

The carrying pulleys are arranged in vaults located at distances 35 ft. apart. A transverse yoke holds the track and slot rails in place. It has a long and flat face, resting on foundations which are independent of the conduit construction. The pulleys are mounted in pairs. The duplicate cables are carried around grooves at different elevations. A conical wheel with spiral grooves pays the outer cable (when in use) down and out to its normal line after the passage of the grip. The grip is arranged on the front end of the car, and is provided with a stationary and a movable jaw. At each end of the jaws is a pair of small carrying pulleys, for supporting the cable and raising it from the grip jaw when the car is at rest. Spools are mounted at each end of the jaws, for ejecting the cable, in case the rope should strand. The grip is reversible, and the cable may be received from either side. The mechanism for operating the jaws is attached to or made part of the grip car, being independent of the grip proper, and the grip may be operated from either end of the car, so that no adjustment of the jaws is required while in transit.

The construction of the driving machinery is as follows : Each pair of driving drums is operated independently through the medium of friction clutch, so that each cable may be individually set in motion or stopped. The driving drums have grooves varied in diameter to meet the contraction of the rope as it is relieved of the strain of operating the road. The incoming cable, having the whole strain, passes into the first groove, and when relieved of a small percentage of the strain, passes to the second groove. The latter groove allows a slight contraction in the cable to take place, and this contraction continues throughout the succession of wraps.

The drums are tilted in opposite directions for the purpose of guiding the cable direct into the grooves when two or three wraps are made, whereas were it not for this tilting of the drums the rope would be carried diagonally from one drum to another, causing much trouble by cutting the grooves and wearing the cable. The principal improvement is in the arrangement of the gearing to meet the angle of these drum shafts ; the shafts being tilted, the gears have straight teeth, while the intermediate and also the driving gears have angular teeth which meet the line of the straight tooth of the tilted gear.

After being wrapped around the drums, as stated, the cables pass to the tension wheel, which is on a car, and traverses a track in rear of the driving machinery, and then it is carried out into the street again.

On the Tenth Avenue Cable Road, of New York City, two Wright engines, 28 × 48, are employed. The driving drums have five grooves each, and are about 12 ft. in diameter ; the first groove on the first drum being the largest. The first groove on the second drum is ⅛ in. less in circumference, and all other grooves are reduced successively in the same ratio. Each pair of driving drums has an independent pair of driving gears, and in the center between the drums a pair of 8 × 8 upright engines are located. These engines are used to move the rope slowly for examination, to take out an old cable or put in a new one, and also are utilized when repairs are made to the main machinery.

It is found that with cables of about 4 miles in length that there is a movement of the tension car of from 4 to 5 ft., so that from 8 to 10 ft. of rope must be disposed of every few minutes. An automatic variable tension device is provided, decreasing or increasing the tensile strain on the contraction of the rope, and so governing the movement of the car.

The Brooklyn Bridge Cable Road.—The cable railway over the Brooklyn Bridge presents the most favorable conditions ever encountered for this mode of propulsion. The road is comparatively short and the traffic is heavy. The track is separate from the roadway, so that the cable, grip, etc., need not be sunk in a conduit, but run over the track bed. The power plant with which the bridge railway began business eight years ago was a modest affair. One set of winding drums and a pair of engines sufficed. The work required rarely exceeded 200 horse-power. In 1888, the increasing traffic demanded additional power, and an entirely new power plant was put in. It consists of three Wright engines, one 30 in. diameter of cylinder by 48 in. stroke of piston, the second 26 in. diameter by 48 in. stroke, and a third 22 in. diameter by 36 in. stroke. A fourth is to be put in, 38 in. diameter by 48 in. stroke.

During the hours of heavy traffic, the work calls for an average expenditure of energy equivalent to 400 or 450 horse-power, and sometimes this runs up to 700 horse-power. As it takes less than 100 horse-power to run the machinery and cables, it is evident that this is the most efficient cable road known, only about 20 per cent. of the power being absorbed in running the cable and machinery, while in street roads 50 per cent. is always allowed for this, and the actual percentage so expended frequently exceeds that figure. The variations in the power exerted are sudden and enormous. Sometimes a preponderance of trains on the down grade will send the engines racing around with throttles shut, and instead of absorbing power will give it out.

The cable-driving apparatus is at the Brooklyn end of the bridge. Two sets of driving

drums are provided, but only one set is used at a time. The other stands idle, and its cable lies on the ties alongside the pulleys on which the live cable runs. In the street roads, using duplicate cables, duplicate sets of carrying pulleys are provided, because the men cannot get down into the conduit to put the spare cable on the pulleys, and throw the other one off when a change is made. This simple process of changing cables can be easily carried out on the bridge, however, as there is no cable conduit.

In all the New York cable roads the cable is driven by being wrapped around two 12-ft. drums, placed in nearly the same perpendicular plane, with their axes about 20 ft. apart. It is a curious fact that though the same cable runs around these two drums, they do not revolve at the same speed. In the bridge cable machinery one drum lags a revolution an hour behind the other. This is supposed by some to be due to the fact that the cable slips or creeps more upon one drum than upon the other. Some engineers think it is simply due to the unequal wearing of the drums, whereby one becomes of less diameter than the other. Inasmuch as it is always the same member of the pair that lags, the first hypothesis would seem nearer the truth. In the bridge machinery this is provided for by a system of automatic gearing, by which the two drums are geared to the driving shaft, much as two horses are hitched to a wagon by an equalizing bar.

From the opening of the bridge railway, September 24, 1883, to November 30, 1891, inclusive, 220,487,283 passengers were carried. Of the delays during the past year, 54 per cent. were occasioned by a failure or defect in some of the several parts of the cable-hauling machinery, and the other 46 per cent. by causes common to ordinary railroad transportation. The grip mechanism failing to act was the cause of but thirty delays, amounting altogether to 2 hours and 57½ minutes out of the 7,300 hours during which the cable was in motion.

Six cables have been used on the bridge, the two now in operation, and the four that have been worn out and thrown away. The following table gives the statistics in regard to them:

Cable.	Condition.	Term of service.		Miles hauled.	Ton miles hauled.	Average No of tons hauled.
		Days.	Years.			
No. 1..........	Worn out.	1,140	3·123	228,329	22,142,706	97·
No. 2..........	Worn out.	607	1·636	120,232	25,492,892	212·03
No. 3..........	Worn out.	393	1·077	82,099	20,395,073	248·42
No. 4..........	Worn out.	356½	0·977	74,111	18,923,467	255·3
No. 5	In use.	267½	0·758	58,881	16,746,912	284·1
No. 6..........	In use.	187	0·512	39,980	12,506,413	312·80

The last column gives the average strain on the cable during use, and of course the ton miles are obtained by multiplying the weight pulled by the number of miles through which it was pulled. As the speed of the cable is constant, and also the distance traveled by each car between taking up and releasing the cable, it is evident that the number of car trips performed on any one cable will vary as the figures in the ton-mile column. These are nearly constant. Cable No. 1, which ran the extraordinary distance of 228,329 miles, was gripped and released only a few more times than cable No. 4, which ran 74,000 miles—about the average life of a cable on a street railway. So it may be that the principal factor in the destruction of a cable is the pinching, crushing action of the grip jaws closing on it, and not its sliding through the grip or turning around corners. Of course this pinching action of the bridge grip is greater than that of the ordinary street-car kind, for the bridge cars are heavier, and the area of contact, being merely that of the point of tangency between a circle and a straight line, is less.

The Broadway Cable Road, of New York City.—At the present time of writing, a road 5.17 miles long is being built in New York City, extending from the Battery to Fifty-ninth Street. The track is set upon cast-iron yokes, which also hold the slot rails and encircle the ends of the sections of the sheet steel cable conduit. The yokes are 27½ in. high to top of lugs, and 23 in. to rail seat. The distance between the yokes is 4 ft. 6 in. They rest upon separate foundations of concrete, which are 45 in. long, 18 in. wide, and 6 in. deep. The conduit in which the cable runs is formed of sheet steel sections, with a backing of concrete. The pits in which the carrier sheaves are located are 42 in. deep and 31½ feet apart. The slot rail is formed of two like but oppositely arranged Z-shaped parts, leaving between them a groove, through which the grip extends from the car down into the conduit, where it engages the cable. The slot rails are braced at frequent intervals by wrought-iron rods passing through the tram rails and through the slot rails. The entire construction is designed to be permanent. The yokes which support the tracks weigh about 550 lbs. each ; the tram rails weigh 91 lbs. per yard, and the slot rails weigh 67 lbs. per yard. Each was specially designed for this work. The gauge of the track is 4 ft. 8½ in., and the distance from center to center of the tracks below Thirty-fifth Street is 9 ft.; above Thirty-fifth Street it is 10 ft. The diameter of the cables will be 1½ in.; the cable drums will be 12 ft. in diameter ; the large rope-driving drums will be 32 ft. in diameter, and the small ones 10 ft. and 7 ft. 6 in. The Corliss engines driving these drums will have cylinders 36 and 38 in. in diameter, with a piston stroke of 60 in.

The following table of information relating to cable roads has been published by the Pacific Cable Railway Co.

Tabular Statement containing Information as to Various Cable Roads in Operation.

NAMES OF ROADS	IN SAN FRANCISCO.						IN CHICAGO.	IN LOS ANGELES, CAL.	
	Clay Street Hill R. R.	Sutter Street R. R.	California Street R. R.	Geary Street R. R.	Presidio R. R.	Market Street Cablo Railway.	Chicago City Cable Railway.	Temple Street Cable Railway.	Second Street Cable R. R.
Gauge of Road	3 feet 6 inches.	5 feet.	3 feet 6 inches.	5 feet.	5 feet.	4 feet 8½ inches.	4 feet 8½ inches.	3 feet 6 inches.	3 feet 6 inches.
Length of road, double track	5,197 feet.	21,090 feet.	12,651 feet.	12,500 feet.	11,000 feet.	$12\frac{3}{10}$ miles.	17 miles.	8,725 feet. Single track.	6,940 feet. Single track.
Heaviest grade	67 feet in 412½.	43 feet in 338.5.	75 feet in 412½.	38 feet in 412½.	78 feet in 412½.	51 feet in 412½.	Level.	72 feet in 800.	80 feet in 400.
Number of engines employed	1—1 spare.	4—2 spare.	1—1 spare.	1—1 spare.	1—1 spare.	4—4 spare.	4-2 spare.	One.	One.
Weight of empty car	2,800 pounds.	4,400 pounds.	4,500 pounds.	4,500 pounds.	4,300 pounds.	Combined, 10,000 lbs.	6,200 pounds.	2,300 pounds.	2,150 pounds.
Weight of empty dummy	2,100 pounds.	3,300 pounds.	4,100 pounds.	4,400 pounds.	4,300 pounds.		6,380 pounds.	2,150 pounds.	2,000 pounds.
Intervals of departure	3 to 5 minutes.	2½ minutes, average.	4 minutes, average.	2½ to 4 minutes.	4 to 6 minutes.	2 to 4 minutes.	2 minutes.	10 minutes.	12 minutes.
Average number of round trips per day	221	253	226	228	210	910	729	96	80
Number of cars and dummies employed	7 of each.	25 of each.	19 of each.	16 week days. 20 Sundays.	15	70 to 80.	240	6 of each.	6 of each.
Hours run per day	17½	19½	19	19	17½	20 hours and 40 min.	20	16	16
Number of wire ropes in use	One.	Three.	Two.	Two.	Two.	Six.	Seven.	One.	One.
Length of ropes used	11,000 feet.	17,900 feet. 16,000 feet. 10,500 feet.	8,840 feet. 17,055 feet.	16,600 feet. 11,300 feet.	12,500 feet. 13,500 feet.	23,958 feet. 21,045 feet. 20,452 feet. 21,702 feet. 5,619 feet. 23,175 feet.	22,920 feet. 4,339 feet. 23,800 feet. 4,369 feet. 23,608 feet. 2,684 feet. 27,800 feet.	18,250 feet.	14,125 feet.
Circumference of wire rope	3 1-16 inches.	3 53-100 inches.	4½ and 4 inches.	3 53-100 inches.	3½ inches.	4 inches.	4 inches.	3 14-100 inches.	3 14-100 inches.
Speed at which ropes travel	528 feet per minute.	8 and 9 miles per hour	537 feet per minute.	600 and 650 feet per minute.	537 feet per minute.	750 feet per minute.	From 8½ to 13 miles per hour.	616 feet per minute.	528 feet per minute.

RAILROAD CARS. VESTIBULE CARS.—*The Pullman Vestibule* provides a continuous connection between contiguous ends of passenger railway cars, forming an entirely closed passageway, preferably of the width of the car platforms, and serving at the same time as a vestibule for entrance and exit to the respective ends of the cars. The connection is made of flexible or adjustable material, so as to constitute a loose or flexible joint that will permit of sufficient movement of each unit car in travel. Fig. 1 is an isometrical perspective view of the end of a car, and Fig. 2 is a perspective view, showing portions of the platform, vestibule, and buffer mechanism, and Fig. 3 shows the complete car. The arch-plate, *a*, forming the open end of a vestibule extension to a railway car when not coupled with another car in a train, and which sustains the outer edge of the flexible connection, is mounted upon the buffer-rod, located below the platform of the car. The buffer-spring, *m*, encloses the buffer-rod. This rod is moved outward by the spring, and inward by the impact of an adjoining car or buffers connected therewith. Upon it is mounted a cross-bar, *l*, in such manner that it can move out and in with the buffer-rod, and at the same time oscillate upon its center as the evener of a wagon does upon the pole. Two rods, *s s′*, are attached to the cross-bar, *l*, by a sort of ball-and-socket joint in such manner that the cross-bar may change its angle to horizontal lines drawn perpendicular to the length of the car, while the rods, *ss′*, always remain substantially parallel with the sides of the car. These rods cannot practically move in any other direction. They project beyond the outer cross-beam of the car, and are there pivoted to the vertical buffer-plate, *n*. Obviously this buffer-plate on one car can not have its acting face coincident with a similar buffer-plate on an adjoining car when the two cars are rounding a curve unless it change its angle with reference to a longitudinal line passing through the center of the car, so that it can be at times at right angles to such a line, and at times at various other angles. The support before described not only permits these changes of angular position, and the in-and-out motions of the buffer-bar, but prevents its center from leaving a horizontal longitudinal line passing through the center of the car, to which it is attached, so that the center of the buffer-bar is always, whether projected or shoved in, practically in line with the center or middle of the platform.

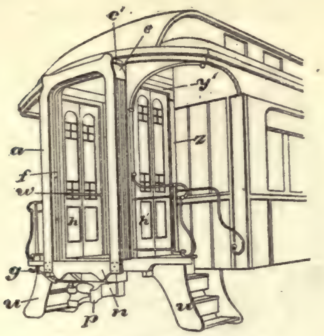


FIG. 1.—Pullman vestibule.

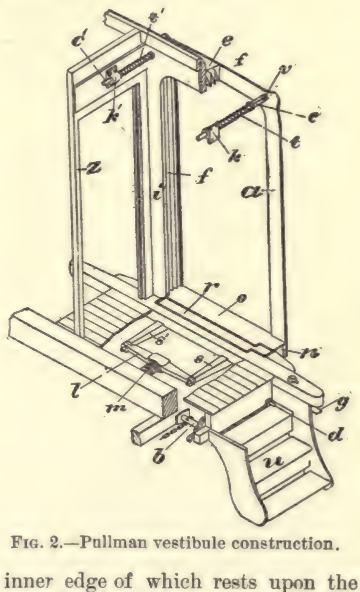


FIG. 2.—Pullman vestibule construction.

Two cars moving in a train vary the distance between the ends of their respective platforms, and also the angles that one of these ends makes with the other, and there is a gap between the platforms. To close this gap there is applied to each of the buffer-plates before described a foot-plate, the inner edge of which rests upon the top of the platform of the car, and slides and turns upon it when the car is in motion. Upon the ends of the buffer-plate is mounted an iron archplate, *a*, which has the same motions as the buffer-plate, and is restrained in the same manner.

When two adjoining cars are coupled, the arch-plates on each car abut one against the other, and they thus abut when the cars are upon straight lines or curves, or are being started, tending to separate, or are stopping, tending to come nearer together. The two arches in adjoining cars therefore make a joint. Each arch-plate has attached to it one edge of a sheet of leather or other flexible material, and at the other edge this is attached to the stanchions. In the spaces between the stanchions, on the same side of the platform, are doors, *h h′*.

The upper ends of the arch-plates are supported from the car body by rods, *c c′*. These rods slide in guides or supports, *k k′*, and are forced outward by spiral springs, *t t′*. The guides, *k k′*, are bolted to the framing supported by the stanchions, and the rods, *c c′*, can move in and out together or independently, but can not practically move sidewise or in lines which are not parallel to a line passing centrally and longitudinally through the car. These rods, *c c′*, have the same motions as the rods, *s s′*, below the platform, and as they are pivoted to the arch-plate, the latter is so supported at top that its top can move, and is restrained in the same way as the foot-plate, the buffer-plate, and the lower part of the arch-plate.

The Barr Vestibule.—Fig. 4 is a section through the end of the car, showing the face-plate and the parallel motion which keeps the plate always parallel with the end of the car.

Fig. 5 shows the exterior of the end of the car and the canvas portion of the vestibule, as well as the door arrangements.

The general features of this vestibule are as follows: There is a face-plate which is carried outward and inward at the bottom of the second buffer, to which it is loosely attached. As the bottom moves out, the top is also carried out an equal distance by means of the links and rod connection which form the parallel motion. There is an adjustment in the connecting-rod which regulates the position of the face-plate.

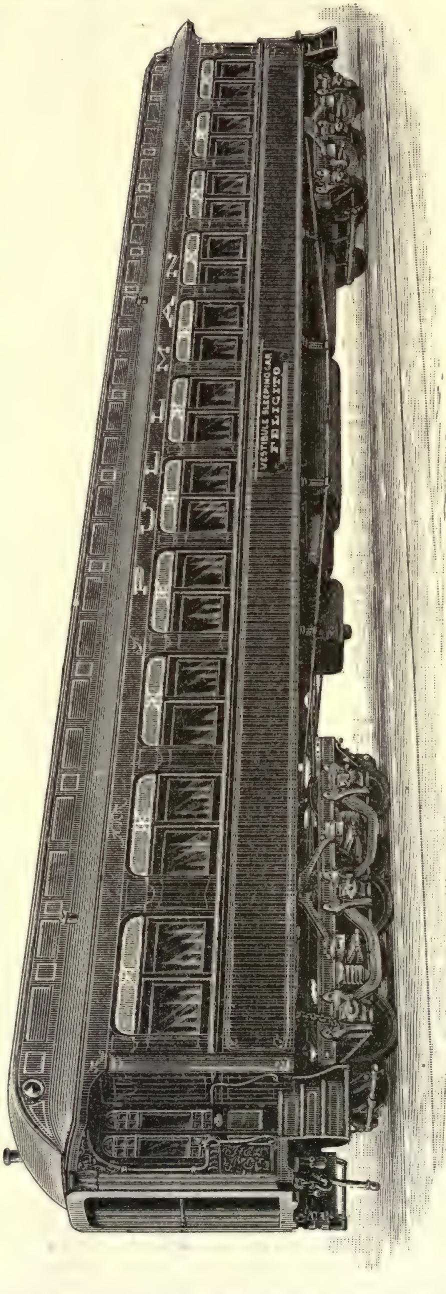


FIG. 3.—Pullman vestibule car.

The Cowell Vestibule is shown in Fig. 6. The main feature aimed at is to so construct the end of a car or coach as to make it convertible at will into either a vestibule or an open car. To accomplish this, the ordinary platform and roof projecting over the platform are supplemented with supports for the roof made to serve as door jambs, and double or folding doors provided for each side of the platform. The curtains are surrounded by a metallic rim, which serves to hold them in place and support the hood, while being flexible laterally to accommodate themselves to the curves of the road. When the vestibules are in use and it is desired to convert the car into an open one, the only requirement is to unlock the curtains, when each recedes into its recess.

STEEL CARS.—*The Harvey Steel Box Car* (Fig. 7).—This car is essentially a steel car, but it has a wooden floor and lining. The center sills are made of 12-in. channels, 20 lbs. per ft., placed 10 in. apart. To these channels are riveted the drawbar attachment, as shown. The center of draft is on a line with the lower flange of the 12-in. channel; thus these channels form not only a strong compression member but a continuous draft rigging as well. The intermediate sills are formed of two 6-in. channels, each weighing $7\frac{1}{4}$ lbs. per ft. They are placed, as shown, with their flanges turned inward and separated just sufficiently to allow a $\frac{3}{4}$-in. bolt to pass between them. They are held from separating laterally by means of clamps above and below, through which the bolts pass. The clamps have lips on the ends which turn down over the channels, as shown.

The side sills are formed in the same way and held with similar clamps and bolts, but the flanges are turned outward instead of inward. On top of the channels which form the intermediate and side sills are placed wooden battens held by $\frac{5}{8}$ in. bolts which pass down between the channels. To these battens a $2\frac{3}{4}$-in. floor is nailed. To further stiffen the center sill laterally, strips of wood are nailed to the floor on each side of the sill. The end sills are formed of two channels, one in front of the other. Between these channels pass the bolts for holding the wooden battens to which the floor is nailed. To stiffen the end sills at the center a horizontal plate is riveted to the end sills and extends outward to the end of the wooden draw-bar stop, shown in the plan and side elevation. This plate acts as a gusset to carry the buffing blows to the intermediate sills. It is 3 ft. long, $\frac{3}{8}$ in. thick, and 10 in. wide. The body bolsters are formed of two 6-in. channels, 5 lbs. per ft., arranged, as shown, with two tension members, 2 in. × 1 in., with T-ends extending over the top of the center sills. This forms a strong and light body bolster, which

for its weight will carry a greater load than any bolster of the ordinary form. To give this body bolster greater carrying capacity, two 4-in. I-beams are inserted between the 6-in. channels and the sills. These extend from side bearing to side bearing across the car. Thus the body bolster is about 16 in. deep at the center. The needle beams are made of 5-in. I-beams extending across the car, as shown. In addition to these lateral braces there are also intermediate braces formed of 4-in. channels bolted to the sills. The posts are formed of pressed steel of U-section and secured by strap bolts at top and bottom, which pass through the sills, the top sill or plate being made in a manner similar to the side sills, but 5 in. deep instead of 6 in. The inclined braces are made of angle iron $3 \times 2 \times \frac{3}{8}$, and the tension rods of $\frac{3}{4}$-in. round steel. The doors are of steel, ingeniously formed into a stiff shape without the use of angle irons. This is probably the strongest door for its weight yet made. It is formed of No. 16 steel, riveted with $\frac{3}{16}$ in. rivets. The end door is of similar construction and mounted on suitable slides. The carlines are formed of No. 9 steel bent to a U-shape and curved to conform with the roof of the car. The U-shape of both the posts and the carlines has been devised for the purpose of receiving the wooden strips to which the corrugated siding and roof is nailed. The car is lined throughout with wood and covered on the outside with corrugated steel, No. 22 B. W. G. The roof is No. 20 B. W. G. This is the most promising steel car that has yet been constructed in this country. (See *Railroad Gazette*, September 18, 1891.)

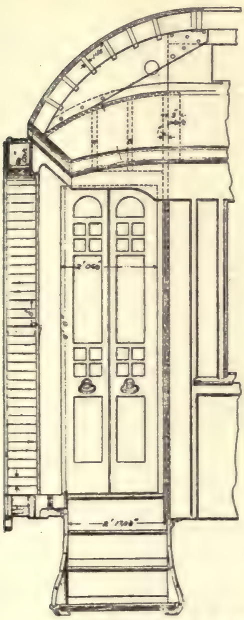


Fig. 4.—Barr vestibule construction.

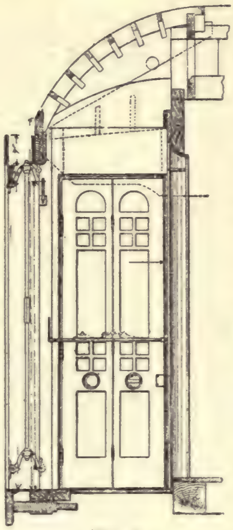


Fig. 5.

Standard Truck.—The general construction and leading dimensions of the standard truck designed for the N. Y. C. & H. R. Railroad are as follows:

It is a rigid truck, with a 15-in. channel bar having 4-in. flanges, for a sand plank. The bolster is 12 in. wide by 11 in. deep, and is trussed by two $1\frac{1}{4}$-in. round rods. This bolster, which is intended to carry about 35,000 lbs., has a safe working strength of 86,000, so that the margin of safety is enough. The axles are M. C. B. standard, with $3\frac{3}{4}$-in. × 7-in. journals. The center plate is of cast-iron.

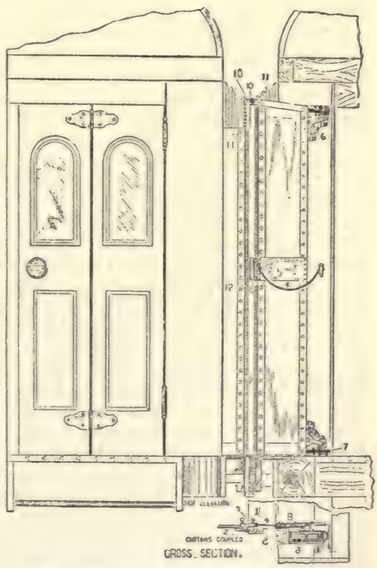


Fig. 6.—The Cowell vestibule construction.

Car Wheels.—In a paper read before the American Society of Civil Engineers, Mr. P. H. Griffin says:

"The best section of wheel depends largely on the service intended and upon the quality and character of the wheel, but certain lines should be followed irrespective of these two conditions on all steam roads. The strains imposed on a wheel are of two kinds: the first consequent on load carried and speed attained; the second that which results from the use of brakes. The first strain multiplies the second in a definite degree. . . .

"It does not follow at all that good wheels will be made because a pattern of proper section is used. That is the first necessity; the second is the method by which the wheels are made. The manufacture of car wheels is hard, laborious work. One man with a helper will turn out on the average eighteen wheels per day. The work is done almost invariably by the piece, and is commenced and finished in ten hours or less. Half of this is given to molding, and the balance to casting. To prepare and finish eighteen molds in five hours necessitates doing the work on one in less than twenty minutes. The most exacting attention to every detail is necessary in preparing and melting the iron. If not given, it may not always produce dangerous conditions, but it

will not produce perfect ones. Any wheelmaker who cannot furnish test bars from his mixture, 1 in. square, and that will carry 2,500 lbs. load between supporters 12 in. apart, is not using a mixture that is what it should be; and if such bars will not carry 2,000 lbs., the wheels are positively dangerous for use. After the wheel is cast it is placed in the annealing pit. Properly speaking, car wheels are not annealed; they are slowly cooled, for the reason that in the process of manufacture the outer part of the tread is cooled and set at a degree of heat lower than that existing in the body of the casting (this on account of the chilling process), and the entire casting must again be brought to a uniform heat and cooled evenly. The cooling pits, as they may be properly called, should be in dry ground. If dampness is found and steam is seen arising from the pits while the wheels are cooling or when they are being removed, shrinkage strains will certainly be found in the wheels, and they will be liable to break in service. When such conditions exist they are always indicated by a reddish color on the wheels when cold. The Pennsylvania Railroad specifications under consideration for adoption by the Master Car Builders' Association accept wheels that do not vary more than $\frac{3}{32}$ of an inch from a true metallic ring placed over them. To place such a ring over a cast surface not tooled would certainly take $\frac{1}{64}$ of an inch all around, making up $\frac{1}{32}$ or $\frac{1}{8}$ of an inch. All things considered, to make castings weighing $\frac{1}{4}$ of a ton and over true to $\frac{1}{16}$ of an inch to center as they come from the foundry, is remarkably good practice. On the question of variation in diameters, $\frac{1}{16}$ of an inch is a very low average. Not alone the original, but the condition after service must also be considered. Flange wear is the leading cause of wheel failure to-day in every type of wheel, and it has grown in exact proportion to the increase in load and speed. The best wheel is the one that will not break, that is mechanically perfect, and that will retain its original conditions for the longest time. The chilled wheel can be made to fulfill these conditions and have a total of 600,000 in every kind of service without one case of breakage as proof of possible safety. One-sixteenth of an inch chilled iron will give more wear than six times that quantity of steel found in any steel tire. It must be remembered that steel tempered and hardened into cutting tools, and steel not so treated, are very different things, and that the latter condition is always the one found in steel tires. Furthermore, the life of a steel wheel in the severe service of to-day is not all in the flat surface of the tire; it is largely in the flange. To provide proper flange thickness on many steel wheels, from 20 to 40 per cent. of the tire must be turned off and thrown away.

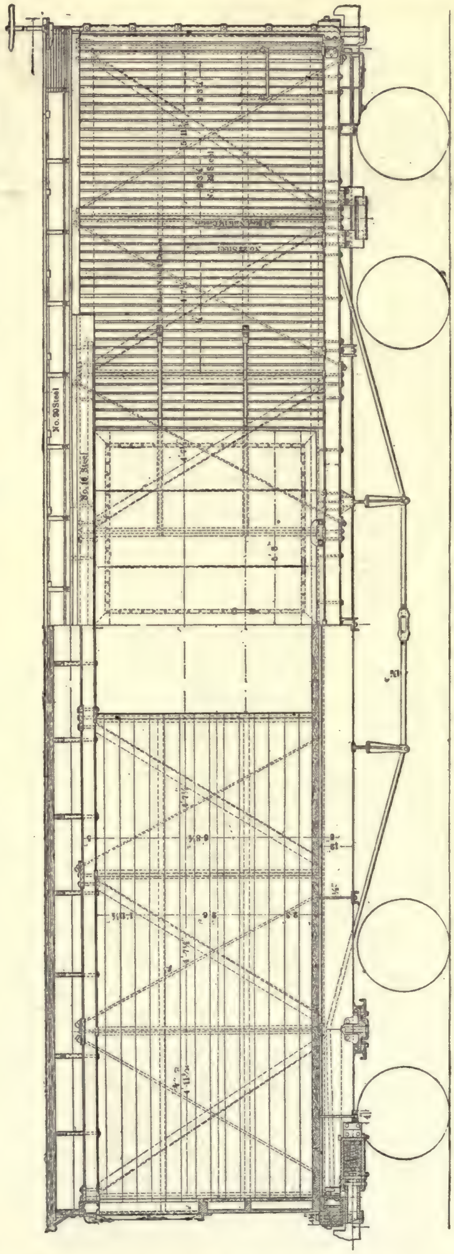


FIG. 7.—The Harvey steel box car.

The author believes that with mechanical conditions such as they should be, and such as can be maintained without difficulty on chilled wheels, the cost of power operating traffic carried over them can be decreased from 15 to 20 per cent. The cost of wheel service can be decreased from 25 to 50 per cent., and the saving in wear on equipment and permanent way will be in like proportions.

The Whitney Contracting Chill for Casting Car Wheels, as patented in 1885 by John R. Whitney, of the Whitney Car Wheel Works, Philadelphia, consists of an outer retaining

ring and an inner chilling ring united to each other by webs of suitable length with open air spaces between them. The inner ring, forming the chilling face, is from $1\frac{1}{2}$ to 3 in. or more in thickness. It is divided into many perfectly separated segments in the process of casting, by the use of asbestos cores. The cores are formed of two thicknesses of thin asbestos paper, enclosing a sheet of blotting paper of the proper thickness. In a 33-in. chill there are more than one hundred of these cores. The segments thus formed are about 1 in. in width, whilst the kerfs separating them are not more than $\frac{1}{50}$ in. wide, which is very much less than it is possible to produce by sawing, especially through a thickness of more than 1 in. By this construction the outer ring is prevented from becoming either quickly or intensely heated by the molten metal of the wheel. It thus retains its original size and shape and acts as a buttress from which the segments must expand inwardly. At the same time, from the well-known fact that liquid iron expands in solidifying, as water does when it becomes ice, the metal forming the wheel expands outwardly as it becomes solid, or is "chilled," and presses firmly against the advancing segments. As these then become more and more heated by this close contact, the kerfs allow them to expand laterally in the direction of the circumference. By careful experiment it has been found that this lateral expansion of a segment 1 in. in width, when heated to redness, is $\frac{1}{100}$ in., so that in the one hundred kerfs before described there is ample provision made for this closing in of the circumference without causing any strain upon the chill either to change its shape, to disintegrate its surface, or to break it in two. At the same time these kerfs are so narrow that they make no injurious ridges, and the treads of the wheels are practically as smooth as if cast in solid chills.

The Boies Steel Car Wheel is built up by two corrugated mild-steel plates bolted to a cast hub, and to an internal flange on the steel tire. The tire is shrunk on before being bolted to the plates. The inner flanges of the plates are also shrunk on each end of the hub. The corrugations of the steel plates insure an elastic, in distinction to a rigid, resistance between the hub and the tire.

Rolling Car Wheels.—A novel machine for this purpose has been designed by Mr. J. R. Jones, of Philadelphia (see *Railroad Gazette*, October 9, 1891). A cast-steel car wheel, blank or bloom, having the hub near the desired proportions, and the web and rim thicker than is desired in the finished wheel, is placed between three rolls—a movable driven tread roll and two side rolls—one of which operates in sliding bearings but is not driven; the other is driven rotating in fixed bearings. The movable tread roll in its sliding bearings is made to approach the side rolls during the continuance of the operation. The tread roll is designed to give shape to the tread and flange of the wheel, and is movable by means of hydraulic pressure to compress, harden, and extend the wheel to any desired diameter while being supported and revolved by the side rolls. The side rolls operate on, compress, and harden the web of the wheel, assist in revolving the bloom, holding it in position to be acted upon by the tread roll. One of these side rolls runs in fixed bearings; the other, which is sliding on bearings, moved by means of hydraulic pressure, rolls the web of the wheel, elongates it, hardens and compresses the metal, moving inward toward the fixed side roll. These side rolls are of greater diameter than one-half the diameter of the wheel. During the operation the metal flows outward from the center toward the rim; at the same time the tread of the wheel is elongated and increased in diameter by pressure being given to the tread roll. The metal of the hub is rolled and hardened by means of the coöperation of the side roll with the steadying rolls. This is done by holding the side rolls on fixed bearings while rotating them, and bringing pressure to bear upon them through the bloom from the steadying rolls.

Rubber-cushioned Car Wheels.—A novel form of car wheel has a rubber cushion between the tire and the wheel center, by which construction it is claimed that the vibrations resulting from uneven track and other causes are prevented (*Railroad Gazette*, September 4, 1891).

Wrought-iron Wheel Centers have been much used at the Baldwin Locomotive Works. The wheels are drop-forged or swaged from parts previously rough shaped, which are not only swaged or die-forged, but are simultaneously welded together.

The Lappin Brake-shoe is made by casting a shoe in a solid piece, from metal combining both strength and softness to a high degree, and with intervening chilled and soft sections of the same metal. The chilled sections radiate into, and mingle with, the soft metal composing the body of the shoe and leave no clearly defined dividing line to form a cutting edge. The soft sections project about $\frac{3}{16}$ of an inch on the face of the shoe.

A series of valuable practical lectures on car wheels was delivered by Mr. R. W. Hunt, in the Sibley College Course, Cornell University, 1890 (see *Scientific American Supplement* of that year).

RAILROAD, ELECTRIC. Some experiments were tried in 1867, at Berlin, in electric railways, by Dr. Werner Siemens, but the work was abandoned because the armature of the Siemens machine then used became heated too quickly and too greatly to be of practical service. Under conditions of more promise, the experiments were resumed by Siemens & Halske in 1879, and carried to a successful issue. The first permanent undertaking executed on the Siemens system was the line between Lichterfelde and the Central Cadetten Anstalt, near Berlin. This installation differed somewhat in detail from the first attempts in the manner in which the current was led; for whereas in the latter a third central rail was used, the former employed only the two existing rails, one as a lead, and the other as a return, circuit.

With the advancing efficiency of the dynamo as a generator, or as a consumer of current, and with the success of the Paris Exposition in 1881, came a revival of interest in the subject of electric railways in America, as elsewhere. At the Chicago Railway Exposition, in May, 1883, Mr. Field exhibited the electric locomotive named "The Judge." The track ran

around the gallery of the main exhibition building, curving sharply at either end on a radius of 56 ft. Its total length was 1,553 ft. The track was of 3-ft. gauge, and had a central rail for conveying the current, the two outer rails serving as the return. The Chicago Electric

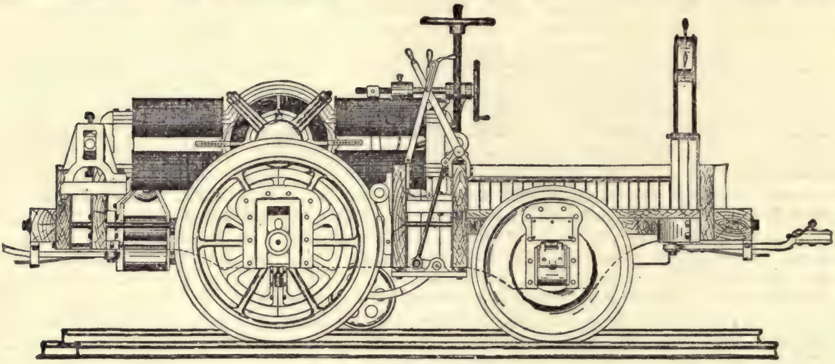


FIG. 1.—Daft electric motor.

Railway was the first constructed in this country for business purposes, and was opened on June 9 and closed June 23, having run in all 446.24 miles. It carried 26,805 passengers. It was afterward sent to the Louisville Exposition during the same year, and there carried a

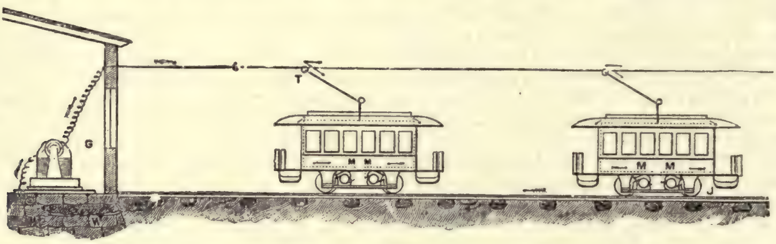


FIG. 2.—Electric railway—trolley system.

large number of passengers. Mr. Thomas A. Edison's work in electric railroading dates back to the spring of 1880, when he built a track at Menlo Park, N. J., near his laboratory. This line was less than half a mile in length. Toward the close of 1883, the experiments of Mr. Leo Daft began to attract attention. The first street railway equipped by the Daft Co. was the Hampden branch of the Baltimore Union Passenger Railway Co., opened for business August 8, 1885. In 1885 the Daft Co. obtained permission to equip a section of the Ninth Avenue Elevated Railway, in New York City, on its system. The road was equipped from the elevated railway station at Fourteenth Street up to Fifty-ninth Street, a distance of two miles, in which a heavy grade is encountered. The motor used was named "Benjamin Franklin," with which a speed of 20 miles an hour was attained. Fig. 1 is a side elevation of this locomotive, which was designed for 75 horse-power and a normal speed of 18 miles per hour, with a possible speed of 40 miles. The motor complete weighs 9 tons and measures $14\frac{1}{2}$ ft. in length over all. The first railway operated under the Charles J. Van Depoele system was laid in Chicago in the winter of 1882-3. The Bentley-Knight Electric Railway Co. made an experimental installation of their conduit system on the tracks of the East Cleveland Horse Railway Co. for a distance of two miles, in 1884, which was in operation for one year.

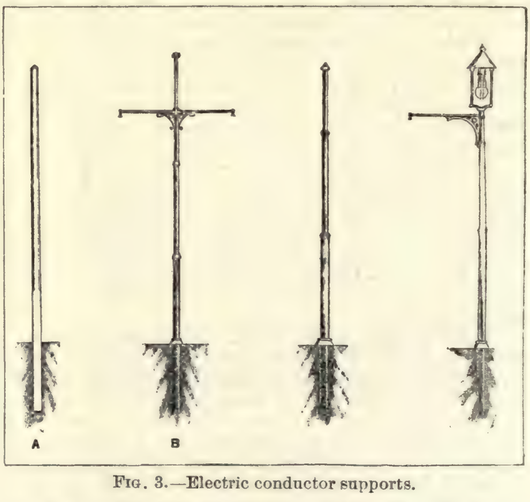


FIG. 3.—Electric conductor supports.

General Method of Operation.—The general principle upon which the modern electric railway is operated is shown in Fig. 2. The current starts from the positive brush of the generator, *G*, passes out to the main conductor, *C*, suspended over the middle of the track, and along this conductor, as shown by the arrows, until it reaches the point, *T*, where the "trolley" of one of the motor cars is in contact with the main conductor. Here it divides, and a portion passes down through the trolley, *T*, to the motors, *M M*, as shown by the dotted lines. After passing through the motors it reaches the rails through the wheels,

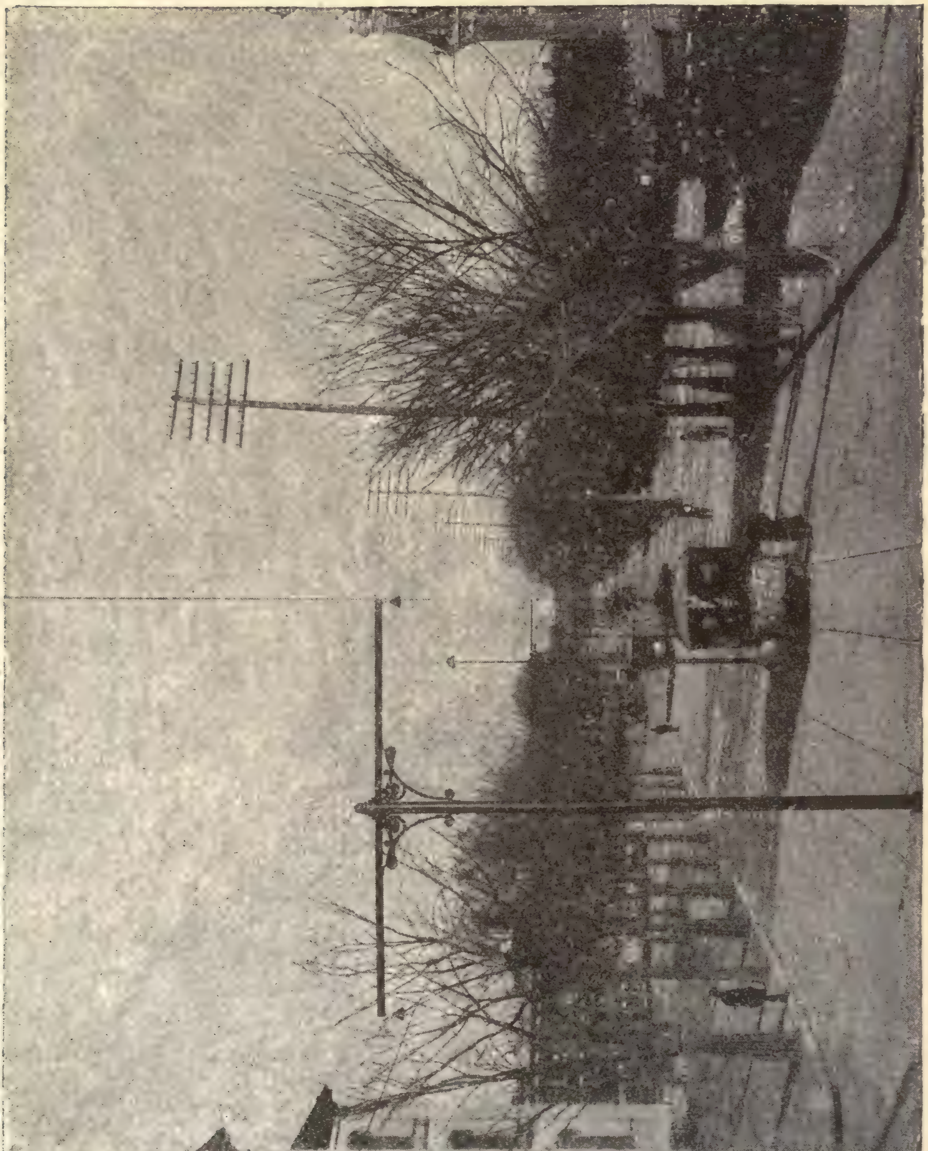


Fig. 4.—View of electric railway at Washington, D.C.

and passes along through the rails and through the return wire, *W*, back to the negative brush of the generator. In other words, it is a "parallel," or "multiple" circuit. The main portion of the current which divided at *T* passes on to feed other cars upon the line in the same manner, the entire current being carried by the rails, each car taking from the overhead conductor exactly the amount of current which is needed to develop the required power. The rails are connected at each joint, *J*, by a copper or iron tie wire riveted to each rail, which makes a perfect electrical connection. The rails are usually "grounded." The electric current is developed at the power station usually by a compound-wound generator,

driven by a steam-engine or water-wheel. This generator maintains a constant electro-motive force, or difference of potential between the overhead conductor and the rails, the current varying according to the requirements of the service, as determined by the number of cars taking current at one time.

There are three methods of supporting the main conductor. Where the track is close to the side of the street, a bracket carries the conductor over the middle of the track, as shown at *D*, Fig. 3. Where the track is double and in the middle of the street, poles with double brackets, as shown at *B*, are sometimes used. The third method, and that most commonly followed, is to place a pole on each side of the street, with a light cross wire strung between them at right angles to the length of the street. From this cross wire the insulating support for the main conductor is suspended. The supports are placed not more than 125 ft. apart. When the line is very long, the traffic heavy, or the grades are very severe, insulated feeder wires are used to supplement the main conductor, to which they are connected at proper points along the line. Fig. 4 shows the method of center-pole construction and trolley arrangement, as embodied in the Thomson-Houston electric road at Washington, D. C.

The Sprague System.—The introduction of the Sprague electric railway motor in 1886 constituted a distinct change in the method of propelling street cars by electricity, and was the beginning of a practice of operation which has become almost universal. The objects sought and accomplished in Mr. Sprague's method were to remove the motor from the car body, place it under the car, make positive connection between the machine and the axle, drive by gearing, and to allow independent movement of the axles, and to preserve elasticity in mechanical connections. Independent driving and positive gearing became cardinal principles, and this necessitated a yielding and preferably cushioned support. To these ends one motor is centered upon each axle, and, to allow the required freedom of motion and at the same time to preserve perfect parallelism in the meshing of the gears, and also for taking part of the weight of the motor off the body of the axle and to throw it onto the journals, one end of the motor is supported by double compression springs, playing upon a loosely supported bolt, which is supported from a cross girder in the bottom of the car or on cross beams supported directly on the side framing of the truck or on equalizing bars carried by the axle boxes. The motors are then, so to speak, weighed or flexibly supported from the car body, and the motion of the armatures being transmitted to the axles through intermediate gearing of compact form and great strength, whenever the axles are in motion there is a spring touch of the pinions upon the gears. Barring friction, a single pound pressure exerted in either direction would lift or depress the motor a slight amount, and no matter how sudden the strain, whether because of a variation of load or speed, or a reversal of direction of rotation, the motor yields to it so as to make the pressure on the gears a progressive one. This support, allowing the armature to have an angular movement several times that of the motor around its axle, makes the strain on the armature much less also. The motors can be carried in the middle space between the axles, or external to them, although the former method is preferable. By detaching the flexible suspension, the motors can be swung around the axle or allowed to hang from it over a pit, where they can be carefully inspected or cleaned.

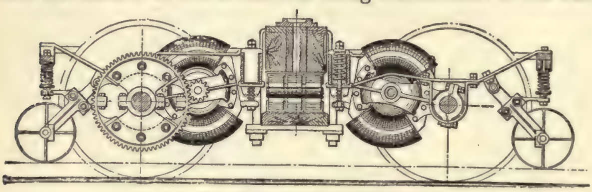


Fig. 5.—Sprague motor.

Mr. Sprague has devised several forms of motors, double and single geared and gearless, to carry out these general principles. The first put into use was designed for compactness, lightness, and high speed on levels. This was a single-geared machine, and the first one was used on experiments on the New York elevated railroad in 1886. The machine (Figs. 5 and 6) consists, in brief, of two curved field-magnets bolted to two pole pieces, the whole carried by brackets on each side, which brackets center on the axle and also carry the armature. The free end of the motor is supported by a bolt and double-acting springs from the transoms of the truck. In this motor the gear reduction is about five to one, and the driving from both ends

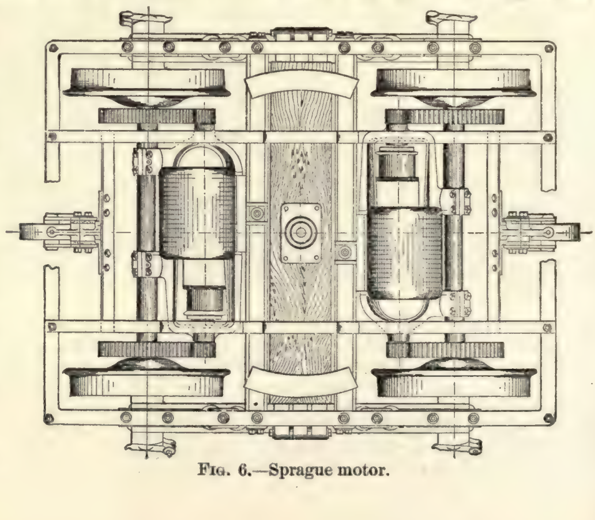


Fig. 6.—Sprague motor.

into gears bolted to the axle. The pinions on the armature shaft are, by a very simple and ingenious construction, set so that the one is half a tooth in advance of the other. For high speed and heavy work this method is very efficient.

In a later type of motors (Fig. 7) the ⊃-shaped magnet has been adopted with a complete wrought-iron magnetic circuit, the gear reduction is double, the armature pinion meshing with the larger of two gears on an intermediate countershaft carried on brackets which engage the main axle, the pinion on the intermediate in turn meshing into a single gear on

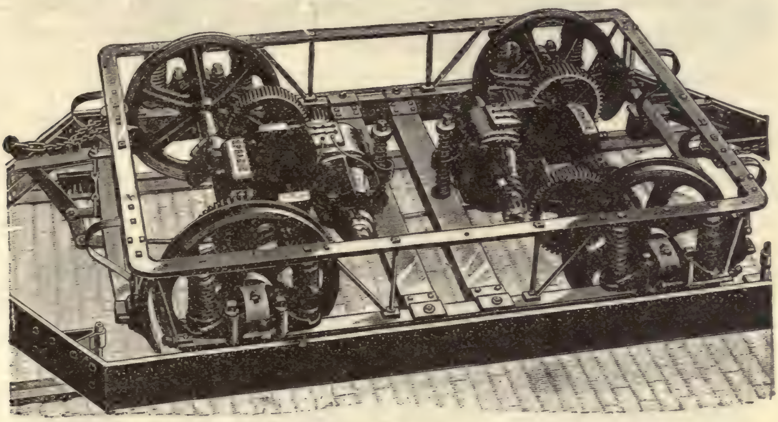


FIG. 7.—Sprague motor.

the axle. This machine has been very widely adopted, and is the plan of double-geared machines now generally employed. The suspension of the free end of the motor has been sometimes made from the car body, but it is more generally carried by equalizing bars yieldingly supported on the axle boxes, so that the resilience and size of the springs that support the car body is undisturbed. The ratio of reduction in gearing is dependent upon the size of the motor and the character of the work required of it. It is essential, on account of the limited space and the necessity of driving both axles, to have two machines, one geared to each axle and independently mounted; the free ends of the machines are inboard, that is, the entire motor equipment is in the space between the axles.

The method of regulating the Sprague electric railway motor is unique, and for the purposes used has proven most economical. The field magnets are wound with three sets of coils of variable numbers of turns and resistances, each occupying the same space and of the same general dimensions. The coils are wound on vulcanized asbestos spools, and are practically made waterproof; these are slipped over the cores of the field magnet, and the terminals attached to wires which go to the regulating switches on the car. The method of winding, connecting, and the development of one-half of a controlling switch is shown in Fig. 8. When the contacts and the switch plates are in the position shown, all circuits in the machine are open; that is, although the trolley-wire or one branch of the multiple circuit is connected to one terminal of one of the field coils, the other terminal and the terminals of the rest of the coils and the armature, as well as the connection to the ground or other part of the circuit, are all open. As the cylinder is rotated beneath the contacts, the first movement throws all of the coils in series with each other and with the armature, and completes the circuit. This interposes a comparatively high resistance in circuit, the machine having a very large number of turns around the field magnet. As the switch continues to rotate, the coils are variously grouped without at any time breaking the circuit from the first position of three in series with each other to three in parallel circuit, changing the effective turns of wire in the proportion of three to one, and the resistance of the field in the proportion of nine to one. By these progressive changes the potential difference at the armature terminals is raised, the field losses with any given current are reduced, and while the speed of the machine is increased the saturation of the field is kept very high. In the last position on the switch, which is the normal one for the machine when operating under a steady and large load, the combined resistances of the field coils as arranged is practically equal to that of the armature, that is ·63 ohm. The resistance of the three coils is 1·27, 1·56, and ·87 ohms respectively, and the resistance of the field varies in the following order: 7·4, 4·86, 3·14, 1·40, and ·77 ohms; while the resistance of the field and armature together is: 8·03, 5·49, 3·77, 2·03, and 1·40 ohms respectively. By this arrangement the field magnetization is the same at the first notch of the switch with 10 amperes of current as it is on the last with 30 amperes, and the torsional effort in the first position with a given current

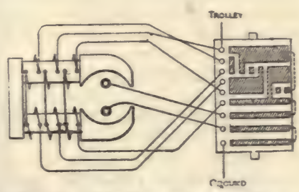


FIG. 8.—Winding and connecting detail.

is about equal to that on the last with double amount. In later forms of machine the coils are of equal resistance and number of turns of wire. While this interferes somewhat

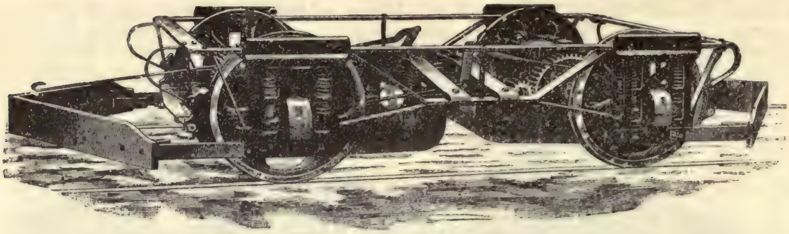


Fig. 9.—Thomson-Houston street car motor.

with the perfect gradation of resistance, it is not a serious objection, and the additional simplicity in manufacture is important.

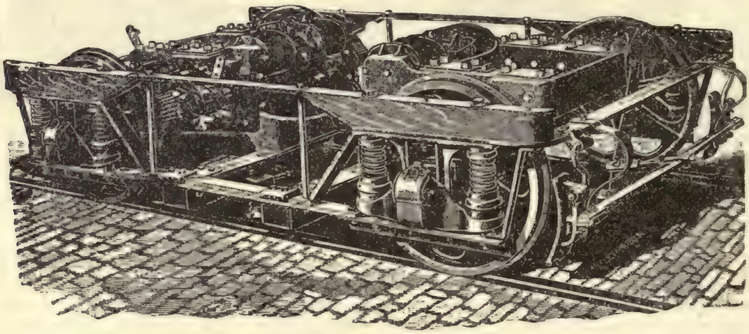


Fig. 10.—Short railway motor.

In actual operation in street-car work, the plates shown in Fig. 8 are duplicated on the switch-cylinder, and the lower connections reversed, so that a single movement of the one switch, without the operation of any other switches, accomplishes the full set of changes in commutation, and the reversal of the current in the armature required for going ahead or reversing. In this way, no matter how sudden the reversal of the machine, as from full speed ahead to full speed back, the movement of the switch-cylinder through an arc of about 300° effects a progressive change through theentire rangeofcommutation in either direction.

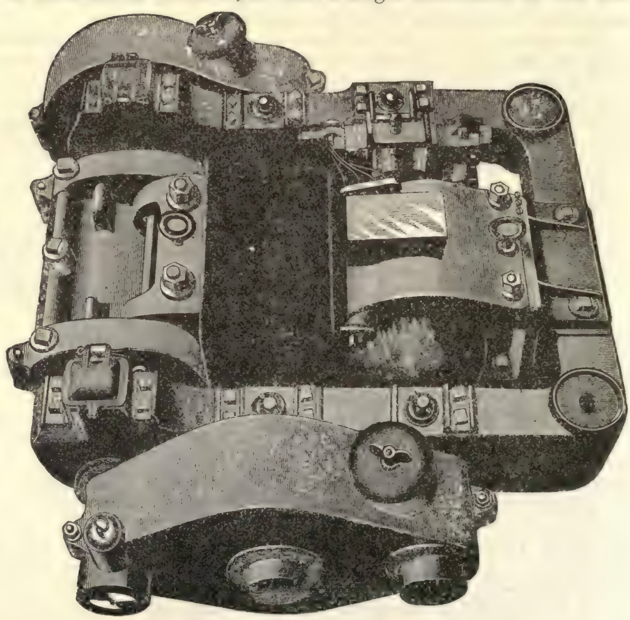


Fig. 11.—Westinghouse motor.

In equipping a car the usual practice is to connect the terminals to all parts of the two motor circuits to a three-way, cut-out box placed in the body of the car, to which are also brought the multiple-arced connections of two switches—one placed on each of the platforms. In one position of the switch the circuits of one motor are cut off from the switches ; in another those of the other motor, and in a third those of neither. The object of this arrangement is to facilitate testing of motors, and also to cut a machine out of circuit in case of accident. Either switch, therefore, has control over either or both motors, as desired.

With heavy grades an arrangement for using the machines as dynamic brakes has been adopted. This consists in connecting lever switches at each platform, so that either the conductor or driver can cut loose from the trolley connection, and close the circuit of the machines upon themselves. In descending a grade, in case the brake chains part, or the supplying system should fail, this gives instant and positive braking control of the car. This latter system is now in use in Florence, Italy.

The Thomson-Houston railway motors, Fig. 9, have the same general appearance as the Sprague motors, but differ somewhat in construction. Ordinarily two 15-horse-power motors are supplied to each truck, and are run in parallel at a pressure of about 500 volts. While the Sprague system had depended entirely on the high resistance of the three-field windings in series to choke down the initial rush of current during the time the motor was starting from rest, the Thomson-Houston engineers preferred to employ an external rheostat for this purpose. The motor fields are wound with what are practically double coils, one or both being employed, as occasion demands. On starting, the rheostat, semi-circular in form, and controlled by a sprocket-wheel, generally operated by a handle on the car platform, offers sufficient resistance to check the initial current. Afterward, as the motor gets up speed, more or less of this rheostat is cut out, and finally the motor coils alone are in series. The current is then said to be "on the end"—that is, both the motor coils are in circuit.

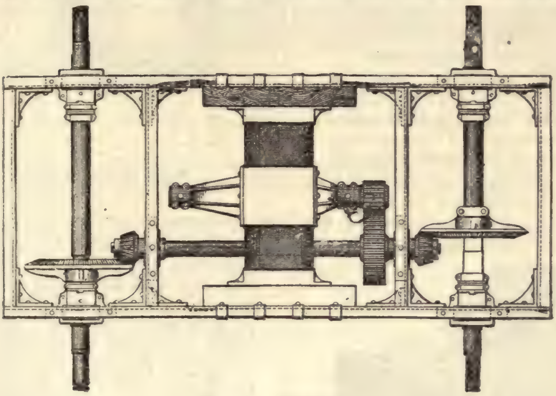


FIG. 12.—Rae motor.

The earlier form of *Short railway motor* is shown in Fig. 10. The arrangement of the field magnets is similar to that of the Brush arc dynamo. The armature is readily accessible for repairs, but the form of the motor necessitates a different construction of truck, as shown in the cut.

In the summer of 1890 the electric railway art took an immense stride forward. The *Westinghouse Electric Co.* brought out a motor possessing some unique mechanical features. The motor proper, Fig. 11, is within a square iron frame that serves both to support it and to furnish bearings for the countershafts for gearing. The body or skeleton of the motor consists of only five parts: The cast-iron frame, the keeper, the two pole pieces, and the brass casting joining the upper and lower pole pieces, forming a mechanical framework of a very strong and simple character. The cast-iron frame carries the car axle, the intermediate axle, and the armature in perfect alignment and parallelism, thus enabling the gears to mesh with great exactness. The pole pieces are hinged to the keeper, and both are firmly held in position by the retaining bolts through the brass casting that joins them at their extremities. The gears are encased in cast-iron boxes, oil-tight, and partially filled with grease. They are thus entirely free from the access of dust and grit, and can be continually and thoroughly lubricated. The armature is of the usual drum type; the core is built up of plates, each of which is cut with a key-way, so that the entire inner structure of the armature can be locked firmly upon the shaft. The double wires of the armature are equivalent in conductivity to No. 7 wire, so that there is little danger of undue heating under the severest strain of service.

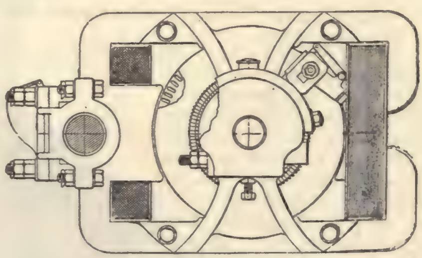


FIG. 13.—Wenstrom motor.

The Rae electric railway system presents some radical differences from any of the others heretofore mentioned. A single motor is used, rigidly attached to the truck, and the armature spindle is parallel to the length of the car. The power is transmitted to both axles from the same motor through beveled gearing. Fig. 12 gives an idea of the principal characteristics of the system. The motor is placed cross-wise of the car, midway between the wheels, and fastened rigidly to the framework of the truck. The armature pinion drives an intermediate gear that, through the bevel-wheels, turns the axles. The motor is of 30 horse-power, with a Siemens armature; it is thoroughly insulated at the sides by oak bars saturated with asphalt, and the employment of raw-hide or fiber armature pinions still further frees the machine from danger of a ground. The whole truck is put together as rigidly as possible, no attempt whatever being made to secure the usual flexibility. The motor is series wound. The regulation of speed is effected through the interposition of a rheostat, consisting of four coils that are successively thrown in parallel arc with each other, and finally short-circuited. The rheostat, with its switch, is placed under the car, as

in the Thomson-Houston, Short, and Westinghouse systems, and is operated from the car platform by a simple handle.

"*Single-reduction" Car Gear*.—The standard Wenstrom street-car motor, Fig. 13, is a 4-pole machine, the magnetic circuit being cast of mitis metal in one piece. It is rated at 25 horse-power, and weighs, complete, very nearly 1 ton. Owing to the powerful magnetic field practicable with the Wenstrom construction, and to the fact of the motor being a 4-pole machine, its speed is only 400 revolutions per minute. The armature is consequently geared directly to the car axle, without the intermediate countershaft. Another ingenious modification of street-car practice due to the Wenstrom Co. is to be found in the Atwood hydraulic gear which forms the connection between the split gear and the driven axle. Its purpose is to furnish a variable clutch between the driving and the driven axle, so that in starting the motor it may be allowed to run free and its power be applied gradually to start the car, and, in addition, to provide a sort of mechanical safety valve, so that when there is a severe overload the hydraulic clutch will slip and allow the armature to rotate fast enough to save it from the excess of current, instead of subjecting it to the dangerous overloading which would otherwise follow. Fig. 14 shows a section of this hydraulic gear.

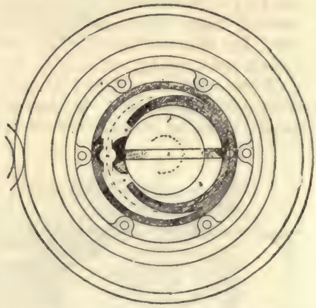


Fig. 14.—Atwood hydraulic gear.

The Thomson-Houston "Single-reduction Gear" is shown in Fig. 15. It is very nearly iron-clad, having two pole pieces of ample surface and carrying two field coils, which partially surround the armature core. The magnetic circuit is completed on the front end of the motor through the face plate, and at the back through the frame on which are cast the axle boxes and arms that serve as a support for the armature-shaft bearings. The armature is of the Gramme ring type, and the bobbins are wound close together around the entire rim. One great advantage of this construction is the fact that any coil can be easily rewound without disturbing its fellows, while with the drum armature, in the type of motor formerly used by the company, the winding all had to be removed down to the injured coil. The motor when mounted on a truck with 30-inch wheels is designed to clear the tops of the rails 4 in. The spur gear on the armature shaft is of steel, $4\frac{1}{2}$ in. face, and has 14 teeth. The split gear on the car axle is of cast-iron, with the same width of face, and has 67 teeth. The speed of the armature shaft relative to that of the car axle is nearly 4·8 to 1; when the car is running 10 miles per hour the armature makes 538 revolutions per minute, or the speed of the armature is 53·8 turns per minute when the car speed is 1 mile per hour. The gears are surrounded by an iron box, so that they may be run in oil.

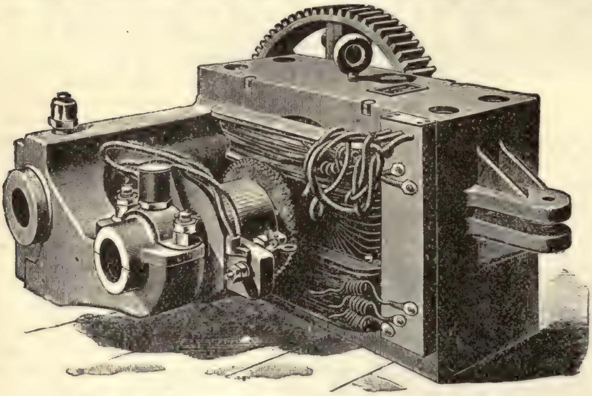


Fig. 15.—Thomson-Houston "single-reduction" gear.

The Westinghouse Single-reduction Car Motor, Fig. 16, has the square form of frame, but the change in the shape of the magnetic circuit, which is circular, makes it possible to utilize four poles with great advantage. They are also rather narrow, and consequently are capable of being magnetized by comparatively short and small windings. The gear ratio is 3·3 to 1. The iron-clad form

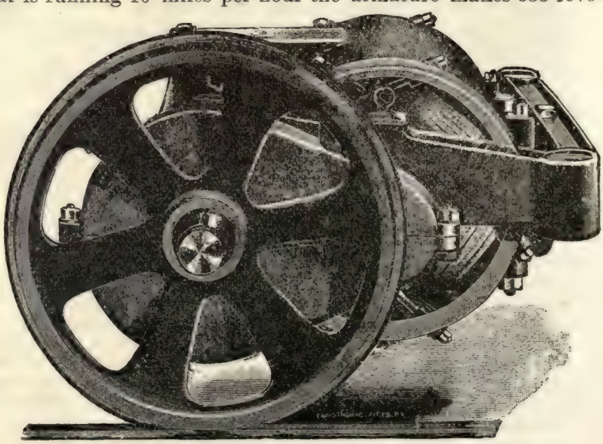


Fig. 16.—The Westinghouse single-reduction car motor.

of the motor enables it to be completely shut in by applying side plates, so that in actual practice it is inclosed so tightly as to be quite free from the numerous difficulties so often experienced from dirt finding its way into the working parts of a machine. The normal speed of the armature at a car speed of about 10 miles per hour is 380 revolutions per minute.

Gearless Motors.—The single-reduction motor was followed by another type in which the armature is mounted directly upon the car axle, thus doing away with all gearing whatsoever. The general appearance of the Westinghouse gearless motor is shown in Fig. 17. It is a 4-pole machine, completely iron-clad, and with the same hinged arrangement of fields as in the other types of Westinghouse motor. The armature is built directly on the car axle, without any attempt at flexible connection; it is of the drum type, 16 in. in diameter, and instead of having a smooth surface, is grooved to receive the wires, thus holding them rigidly in place. The total depth of the field magnets over all is but 20 in., giving 5 in. clearance between the bottom of the motor and the tread of the 30-in. wheel.

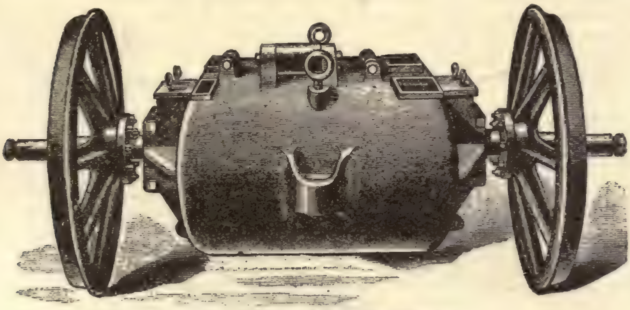


FIG. 17.—Westinghouse gearless motor.

In the *Short* gearless motor the same style of armature is employed as in the ordinary Short motor—that is, a flat Gramme ring of many sections, with a magnetic circuit arranged like that of the Brush dynamo. The motor and its connections are shown in section in Fig. 18. The armature itself is not mounted, as in the Westinghouse motor, directly upon the axle, but on a hollow shaft concentric with it, with plenty of inside clearance. The armature proper consists of a laminated iron core of the usual Short type, wound in a large number of independent segments. The commutator is mounted on the same hollow shaft as the armature, and close to it. The motor is really a 4-pole machine. The field coils are bolted to a circular frame at each side of the motor, in the center of which are the bearings that carry the hollow armature shaft. The spring connections for easy starting are shown in the cut. A double arm, running out from the framework to the cross-girders of the truck makes provision for supporting the entire motor. A 36-in. wheel is generally employed, giving a clearance of $5\frac{1}{4}$ in. over the track. At a speed of 10 miles per hour, the armature drives a 36-in. car-wheel 94 revolutions per minute; the equivalent speed of a single-reduction motor would be about 400.

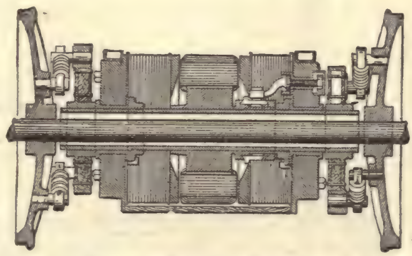


FIG. 18.—Short gearless motor.

Probably the first gearless motor for street cars was the Eickemeyer-Field, the peculiarity of which is

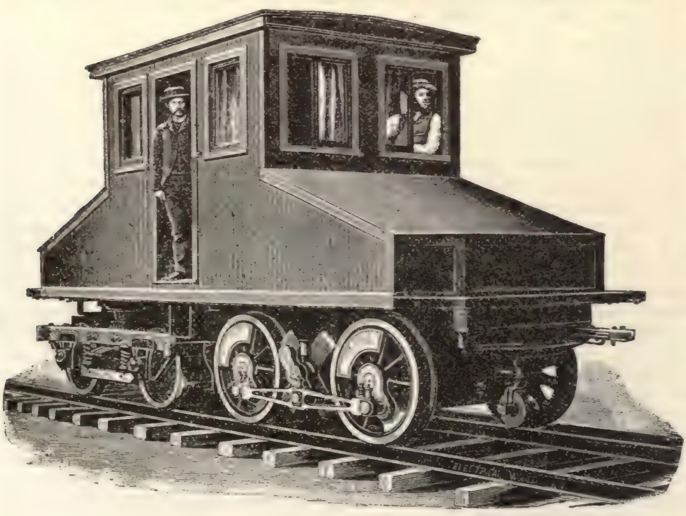


FIG. 19.—Field electric locomotive.

the use of a motor not connected to the axle, but operating through the medium of a connecting-rod, driven direct from a crank on the armature shaft. The motor is iron-clad and singularly compact.

The method adopted is illustrated in Fig. 19, which shows the Field locomotive that ran for some time on the New York elevated railways.

The type of locomotive employed on the City and South London Railway, London, underground, is shown in Fig. 20. Each locomotive is capable of developing 100 effective horse-power, and of running up to 25 miles per hour. The armatures of the locomotives are constructed so that the shaft of the armature is the axle of the locomotive ; in this way all intermediate gear and all reciprocating parts are entirely avoided. A motor is fitted on each axle, as shown in the cut, the axles not being coupled, but working independently. The current is conveyed from the collecting shoes, through an ammeter, to a regulating switch, then to a reversing switch, thence to the motors, and back through the framework of the locomotive to the rails, so completing the electrical circuit.

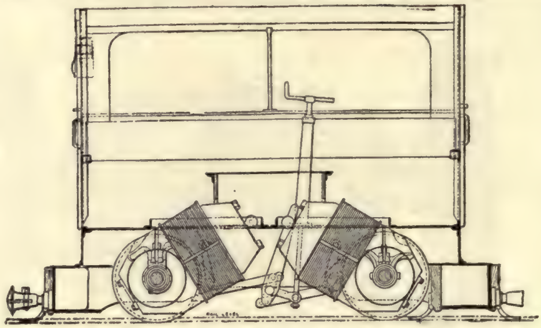


FIG. 20.—London underground railway motor.

Underground Conductors.—Mr. S. D. Field has invented an electric street-railway system, designed to avoid the use of overhead wires. Fig. 21 shows the general method of construction. The wheels shown are 30 in. in diameter, and the conduits themselves are only 8 in. high. They are built up in lengths from two sections bolted together at the bottom, and let into the wooden cross-ties, leaving a slot at the top. It will be noted that the wheels have different treads on each side of the flange, the inner being of smaller diameter than the outer tread. On a straight track the outer, larger tread of each wheel bears on the track. But when rounding curves, the wheel bears on the smaller tread on the inner rail, so that it has a slower motion than the outer wheel, and thus the friction usually encountered is avoided. The angle-rails, which are bolted to the tops of the conduits, are raised only one-fourth of an inch above the level of the pavement, and, being rounded, present no obstruction to ordinary traffic. The conductors are supported in the conduit by insulating hangers. An underground system based on this principle has been in operation in Budapest, Hungary, since 1890. A number of attempts have been made to avoid the use of the slot in streets, and several systems have been devised by means of which a cable buried beneath the surface is connected to the car circuit by switches placed at intervals and operated by mechanism, such as attracting magnets on the car. Among these systems are those devised by Pollak & Binswanger, McElroy, Lineff, and others. They have not, however, come into general use.

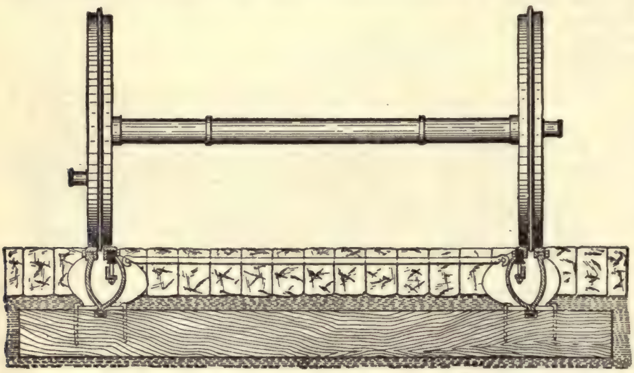


FIG. 21.—Underground conductor.

Accumulators, or storage batteries, are used to a limited extent for the operation of electric railways. By this method the stored energy, conveyed to a motor in the form of current, sets it in motion, and with it the car. Looked at from the standpoint of *convenience* and *applicability*, the propulsion of tram-cars through the medium of accumulators must be conceded to be second to no other. The batteries occupy no valuable space, being stowed under the seats, while the motor can be placed under the car body. London, Brussels, Paris, New York, Philadelphia, Boston, Washington, and San Francisco, have all seen tram-cars run by accumulators. In Berlin, Mr. A. Reckenzaun made a successful demonstration with his motor applied to street cars, and deriving current from accumulators. Fig. 22 shows the car, in part sectional elevation. The various arrangements may be classed under the following headings, viz. : 1. The battery. 2. The motors. 3. Transmitting gear. 4. Speed regulation. 5. The brakes.

(1) The battery consisted of 60 cells, each weighing 40 lbs., and with a capacity of 150

ampere-hours. They were placed on a board under the seats of the car, resting on rollers, so that they could be readily run in and out. There were two rows of 15 cells each under each seat. They were coupled in series, and hence gave an electromotive force of from 110 to 120 volts.

The storage batteries were changed every two or four hours, according to the length of the trip, and the change could be performed in about three minutes, not occupying more time than a change of horses.

(2) The electric motors employed were of the Reckenzaun model. They weighed 420 lbs., and were capable of delivering from four to nine horse-power. At 120 volts their efficiency was 75 per cent., and at the nominal speed of 7 miles per hour they made 1,000 revolutions per minute. But this speed could be raised to 10 miles per hour.

(3) The car body was mounted upon two trucks, each of which carried a motor ; and

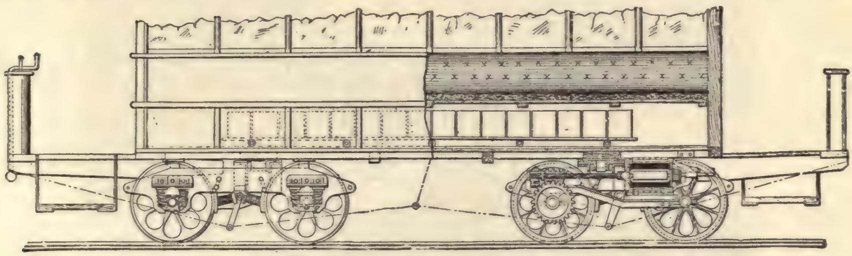


FIG. 22.—Car driven from storage battery.

worm gearing was employed to transmit power from the armature shaft to the axles of the wheels.

(4) Changes in speed were effected by different combinations between the whole battery and the two motors.

Two forms of brake could be brought into play on the car : the ordinary mechanical, and the electrical brakes. The latter were called into action automatically when the switch cut off the battery current. The motors were then converted into dynamos which generated a current that was sent into the coils on the brake-shoes, magnetizing them so that they were attracted by, and pressed against, the wheels. At the same time the resistance encountered by the armature turning in the magnetic field also acted powerfully to retard the speed, and both these acting together brought the car rapidly to a halt.

THE PORTELECTRIC SYSTEM, invented by J. T. Williams, is designed for the rapid conveyance of mail and express matter between distant points. The carrier, Fig. 23, is a hollow, cylindrical projectile of wrought-iron, with ogival ends, the cylindrical portion being 8 ft. long and 10 in. in diameter, the length 12 ft. over all, and the weight, approximately, 500 lbs. It has capacity to contain, say, 10,000 letters, weighing, perhaps, 175 lbs. It is provided with two flanged wheels above, and two underneath, all of which, being fitted with ball bearings, revolve with very slight friction. The propelling power is derived from a series of hollow helices of insulated copper wire, each of which encircles the track and carrier, Fig. 24. These are fixed along the permanent way at intervals. A contact wheel, mounted upon the carrier, and running in contact with the upper track-rail (which is divided into sections, and utilized as an electric conductor), connects the several helices in succession with the source of electricity as the carrier moves forward upon the track. The actual cost of the electric power required to propel the carrier at 150 miles per hour is claimed to be five cents per horse-power hour, including cost of attendance at stations. The mere cost of *power* for propelling a carrier from Boston to New York would, therefore, not exceed seventy-five cents per trip. Excessive estimates of the cost of a double-track line, making liberal allowances in all directions, do not exceed $35,000 per mile, or about $7,000,000 for a line between Boston and New York. It has been proposed to use this system for speedy mail delivery in New York City.

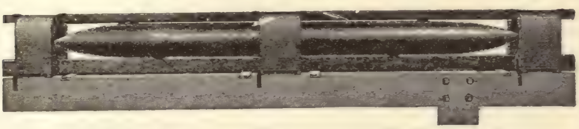


FIG. 23.—Portelectric system, carrier.

TELPHERAGE.—Telpherage is the name given to a system devised by the late Prof. Fleeming Jenkin, and worked out by Professors Ayrton and Perry, of transportation of goods and passengers by overhead suspended cars driven by electric motors. Generically considered, a telpher line system consists of a rod or rail track of considerable length, suspended several feet from the ground, connected with a source of electricity placed at some convenient place at or near the course of the track, and traversed by an electro-locomotive which derives its motive power electrically from the track, draws a number of small holders of freight or passengers, and is controlled, as to its motion, from a place or places other than itself. On the telpher line built at Weston, England, the wire is five-eighths of an inch in diameter.

The load is carried in seven skips, the first being seen in Fig. 25. About half a ton can be put into each skip and a speed obtained of six miles an hour. The principle of the system of telpherage is best shown forth in a commercial line that was put into operation at Glynde, England, to carry clay from a pit to the Glynde railway siding, whence it was delivered into trucks and taken by rail to its ultimate destination.

DATA OF ELECTRIC RAILWAY CONSTRUCTION AND MAINTENANCE.—The electric railroads of

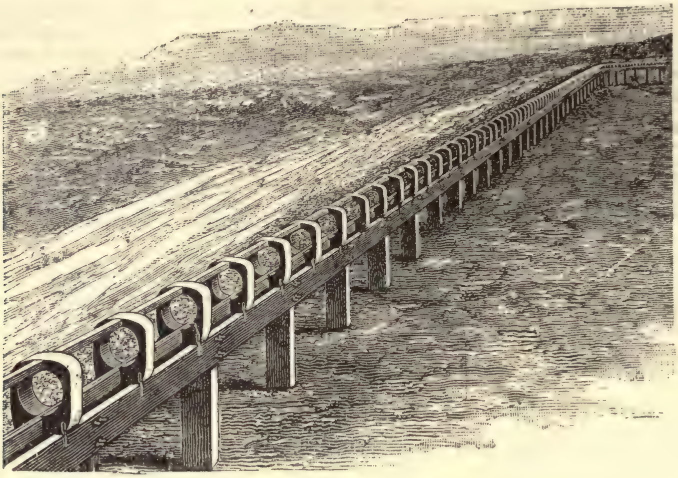


FIG. 24.—Portelectric system, track.

the United States now (January, 1892) number nearly 500, and they have been in operation long enough to furnish some very interesting data as to the cost of construction and maintenance, whether as compared among themselves, or as contrasted with horse or cable street railways. It is to be noted, however, that many of the earlier roads were crude, and hence are expensive to operate, while in other cases the original cost of equipment as horse railroads still figures as part of the investment upon which the electric service has to pay dividends. The tables presented here are the result of a careful investigation of the subject in 1891. Table I. shows that, taking street length as the unit of comparison in the cases of the roads under consideration, the total permanent investment of the electric roads is only 15 per cent. more than that of the horse roads, while the cable roads cost more than nine times as much as the electric roads. The average speed of cable and of electric cars is about the same; consequently the cable roads ran about four times as many cars per mile of street length as the electric. This would be expected, as the cable roads generally occupy the routes of heaviest travel. The horse roads ran more cars than the electric, for an equal length of road, but

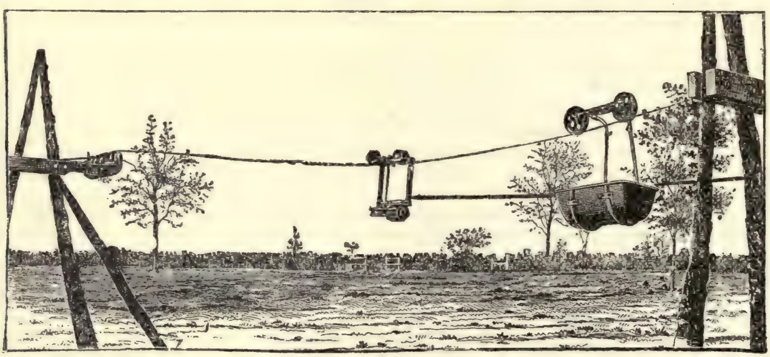


FIG. 25.—Telpherage—track and motor.

the latter, having an advantage in higher speed, greatly exceed in car miles run. The electric roads carried fewest passengers per car mile, but carried nearly as many per mile of street occupied as the horse roads. On account of their more favorable location, the cable roads exceed both the others in passengers per mile of route. The column showing passengers carried per mile run gives a general idea of the relative number of passengers on a car at any one time.

TABLE I.

Comparison of Investment and Operating Expenses.

	Total investment, real estate, road and equipment.		Car miles run per annum, per mile of street length.	Passengers carried annually per mile of street length.	Passengers carried per car mile run.
	Per mile of street length.	Per mile of track length.			
* 22 Electric roads.........	$38,500	$27,780	76,158	237,038	3·10
† 45 Horse roads.......... .	33,406	31,093	43,345	251,816	5·81
‡ 10 Cable roads...........	350,325	184,275	309,395	1,355,965	4·38

* Car miles run per annum, 14,013,187 ; passengers carried per annum, 43,614,972 ; street length, 184 miles ; track length, 255 miles.
† All the roads in Massachusetts operated exclusively by horses for 1885-90. Average for six years.
‡ From U. S. Census Bulletin No. 55.

In Table II. we have operating expenses per car mile, with all taxes and fixed charges excluded, for the three systems ; the interest charge per mile at 6 per cent. upon the total permanent investment ; the total of operating expenses and interest per car mile ; the cost per passenger carried, interest charge excluded, and the same with interest charge included.

TABLE II.

	Operating expenses per car mile run. (cents.)	Interest charge per car mile at 6 per cent. on total investment. (cents.)	Total of operating expenses and interest, per car mile. (cents.)	Cost per passenger carried, interest excluded. (cents.)	Cost per passenger carried, interest included. (cents.)
Electric roads.............	11·02	3·03	14·05	3·55	4·53
Horse roads..................	24·32	4·62	28·94	4·18	4·98
Cable roads..................	14·12	6·97	20·91	3·22	4·77

It deserves pointing out that, as cable roads operate only in centers of dense population, they carry at present four times as many passengers per car mile as the electric cars, few of which have yet penetrated to the heart of the larger cities, and hence the slightly lower cost per passenger shown by the cable roads.

In Table III. we have the ratios of the three most important items, and the proportional traffic that must be done per mile of street occupied, for each system, to pay operating expenses and 6 per cent. on the investment.

TABLE III.

	Ratio of investment, per mile of street length.	Ratio of car miles run annually per mile of street len th.	Ratio of cost of operation per car mile, interest included.	Proportional traffic that must be done, per mile of street occupied, to pay operating expenses, and 6 per cent. on the investment.
Electric roads	1·152	1·757	·485	·852
Horse roads.................	1·000	1·000	1·000	1·000
Cable roads.................	10·486	7·138	·722	5·154

A few details are now in order as to the nature of the work done by electric roads in furnishing cheap passenger transportation. It will be seen from the subjoined Table IV. that many of the items are susceptible of wide variation.

TABLE IV.

Seven Representative Roads, operated entirely by Electricity.

ROAD.	LENGTH. Of all tracks.	LENGTH. Of road.	Passengers carried annually per mile of road.	Number of cars in daily operation.	Average daily mileage per car.	Average number of passengers daily per car.	Passengers carried per car mile.	Operating expenses per car mile.	Operating expenses per car per day.	Cost per passenger carried.
								Cents.	Dollars.	Cents.
1	8·5	5·0	*460,000	20	83	318	3·82	11·82	9.80	3·09
2	16·0	10·0	199,000	16	125	343	2·75	8·43	10.54	3·07
3	51·0	35·0	*162,857	50	100	313	3·13	12·29	12.29	3·93
4	40·0	19·5	487,582	140	91	188	2·06	7·80	7.10	3·79
5	15·5	14·0	167,511	18	106	357	3 35	11·00	11.70	3·28
6	28.0	23·5	286,852	31	108	597	5·51	12·74	13.76	2·31
7	3·8	2·8	200,000	5	92	307	3·33	8·49	7.81	2·55
	162·8	109·8		280				†9·83		†3·28

* Estimated. † Averages.

Total annual car mileage, 9,862,000. Total number of passengers carried annually, 29,144,000.

The items of expense in the operation of electric street railways may be divided into—roadbed and track ; maintenance of overhead line ; maintenance of power plant ; total cost of power making ; repairs to rolling stock ; incidental transportation expenses, and what may be called executive charges. Below is given Table V., which supplies the averages of 22 American electric trolley roads, varying in length from 3 to 51 miles, with from 3 to 140 cars in daily operation, making 80 to 150 miles daily per car, or an average of 110 miles for each car.

TABLE V.

Detail of Operating Expenses of Electric Roads.

	EXPENSES PER CAR MILE. (CENTS.) Highest.	Lowest.	Average.
Maintenance of roadbed and track	1·86	·10	·54
Maintenance of line	·95	·01	·12
Maintenance of power plant, including repairs on engines, dynamos, buildings, etc.	·86	·05	·36
Cost of power, including fuel, wages of engineers, firemen, dynamo tenders, oil, waste, water, and other supplies	4·95	·48	1·96
Repairs on cars and motors	5·24	·59	1·80
Transportation expenses, including wages of conductors, motormen, starters, and switchmen, removal of snow and ice, accidents to persons and property, etc.	9·47	2·74	4·98
General expenses, including salaries of officers and clerks, office expenses, advertising, printing, legal expenses, insurance, etc	2·95	·79	1·26
Total	*22·99	*7·80	11·02

* Respectively the highest and lowest total for any one road.

These figures bring out some interesting facts as to the mechanical and steam-engineering features of this work. The cost of coal on the above roads varies from $1 per ton for slack, to $3 for R. O. M. (run of mine), and $3.80 for lump. The wages of conductors and motormen vary from 10 cents to 20 cents per hour. The consumption of coal varies from 4.3 lbs. of slack per car mile to 12.2 lbs. R. O. M. per car mile.

The station output varies from 3.7 E. H. P. (electrical horse-power) to 8.4 E. H. P. per car in operation, for roads equipped with 16-foot cars and Edison motors. In the latter case the road had many heavy grades and sharp curves. One road, equipped with 30-foot double truck cars (weight complete about 10 tons), 15-horse-power equipments, traffic medium and grades moderate, required an average of 10.7 E. H. P. per car in operation.

The best station performance here included is 1 E. H. P. for every 5 lbs. of slack or 4 lbs. of nut consumed ; and evaporation of 7½ lbs. of water for every pound of slack consumed.

The following is an estimate of electric railway equipment, using the trolley system :

The cost of an electric car equipment, including two motors, truck and car body complete, is from $3,200 to $3,500. There should be installed in generating capacity for power plant, twenty to twenty-five horse-power per car operated, which will give reserve power. One mile of single track construction will cost complete, with 65-lb. girder rail, ties 2½ ft. on centers, bonding of rails, paving, etc., $9,000 to $10,000. The cost of the electric part of power plant, including generators, switch-board, etc., installed, is $35 to $45 per horse-power.

Line construction per mile, complete, including track bonding, plain pole work, cross sus-

pension or bracket with feed wire, $2,000 to $2,500. Sawed and painted poles, $2,500 to $3,000. Iron poles, concrete setting, cross suspension, double track, feed and guard wires, $6,500 to $7,500. Same with center poles, $4,500 to $5,500.

An electric car averages 100 to 125 miles a day.

Cost of Electric Equipments for Street Railroads.

No. of cars.	Steam plant. H. P.	Capacity of generators. K. W.	Steam plant.	Station electrical equipment.	Car equipments, boilers, trucks and motors.	Line construction, ½ mile of double track, per car.	Total equipment, omitting track.
6	120	80	$7,000	$6,400	$19,500	$15,000	$47,900
10	225	150	11,000	10,500	32,500	25,000	79,000
15	375	240	17,500	15,000	48,750	37,500	118,750
20	450	300	22,000	17,500	65,000	60,000	164,500
30	675	450	28,000	22,000	97,500	90,000	237,500
50	1,125	750	50,000	33,000	162,500	187,500	433,000
100	2,025	1,350	90,000	60,000	325,000	375,000	850,000

The above figures are approximate only, and based on the best city railroad practice.

[For more detailed information on Electric Railways, the reader may consult Martin & Wetzler's *The Electric Motor and its Applications*, Crosby & Bell's *The Electric Railway*, and the electrical journals.]

Railroad Signals : See Switches and Signals.

RAILS. In the decade from 1880 to 1890 but few changes have taken place in the theory or practice of construction and maintenance of the permanent way of railroads. One important change has taken place, in the United States at least, in theory, and to some degree in practice. That relates to the form, weight, and composition of rails. The iron rail no longer exists except as a relic. In 1880 there were in the tracks of the United States, 70,741 miles of iron rail, and 37,329 miles of steel (Tenth Census). At the end of 1890 there were still 40,700 miles of track laid with iron and 167,600 miles with steel. (Poor's *Manual.*) The question of steel or iron rails was settled long before 1880, and, in fact, commercial rolling of steel rails began in the United States in 1867. The important change of the last decade has been in the steel rail itself. In 1880 rail makers and railroad engineers had begun working on the theory that a comparatively soft rail would wear better than one considerably harder. Accordingly, rails were made with about 0.30 per cent. of carbon. The influence of this theory became still more marked by 1885 or 1886, and indeed the doctrine has not yet been absolutely disproved, but it has been shown to be so improbable, that the hardness of rails is being increased quite generally. The practice in the United States now is to use 0.40 to 0.60 per cent. of carbon, according to the weight of the section, with a tendency to 0.50 or 0.55 as an average. The most recent example of a heavy rail, designed to be high in carbon and stiff in section, is the Boston & Albany Railroad Co.'s rail, 95 lbs. per yard, rolled by the Bethlehem Iron Co., in 1891. This is the heaviest rail used in the United States up to the end of 1891. (A rail weighing 100 lbs. per yard has been laid in the St. Clair tunnel, Grand Trunk Railway.) This Boston & Albany rail is important as an example of late and good practice in composition and design. Its general outline is shown in Fig. 1. The chemical specifications call for carbon 0.60, and phosphorus not to exceed 0.06 per cent. Physical tests give an elastic limit of 55,000 to 60,000 lbs. per sq. in., and from 12 to 18 per cent. elongation. In England the percentage of carbon has long been about 0.40, and in France it is much higher. Rails above 0.60 per cent. carbon are common there, and they often run as high as 1 per cent. The theory of the better wear of very soft rails never affected steel rail practice so much in France as in the United States.

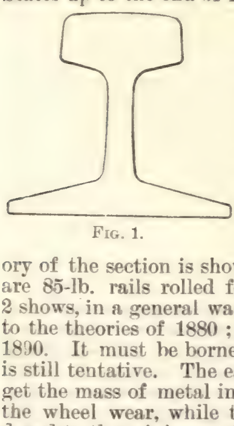


Fig. 1.

The change in the theory of the section is shown by Figs. 2 and 3. These are 85-lb. rails rolled for comparative trial. Fig. 2 shows, in a general way, the best section according to the theories of 1880 ; Fig. 3 shows the theories of 1890. It must be borne in mind that the later form is still tentative. The earlier section was adopted to get the mass of metal in the head of the rail to take the wheel wear, while the web and flange were reduced to the minimum dimensions which would give reasonable bearing on the ties, endurance against corrosion, and vertical stiffness. The result was disappointing. It gradually appeared that the rails with large heads did not wear as

Fig. 2.

Fig. 3.

long as rails of earlier make, with smaller heads, even when these last were of considerably lighter section. The investigations of engineers, rail makers, and students have gradually crystallized into the doctrine that the mass of metal in a steel rail should be disposed not merely with regard to wheel wear and to get stiffness as a beam, but so that the metal in the head shall be thoroughly worked by the rolls, and that the cooling shall be uniform throughout the section, as nearly as may be. In the type of section shown by Fig. 2, the distribution of metal is about: Head, 47.51 per cent.; web, 18.95 per cent.; flange, 33.54 per cent. In Fig. 3 the proportions are: Head, 41 per cent.; web, 21.46 per cent.; flange, 37.54 per cent. In the latter section the metal in the head, although less in mass, is better compacted, and defects in the ingot are more likely to be worked out; besides, cooling strains are less, and less straightening of the rail is necessary in the mill. The more modern theory appears to be borne out by facts, but some years must pass yet before it is absolutely demonstrated to be correct. (See for discussions of these matters, Trans. A. S. C. E., 1888 to 1891; Trans. Am. Inst. of Mining Engineers, 1888 to 1891; and technical journals, especially the *Railroad Gazette*, 1886 to 1891.)

The average weight of rails rolled in the United States in 1891 is estimated by the makers at between 65 and 70 lbs. per yard, but many have been rolled of 75, 80, and 85 lbs., and some of 90 and 95 lbs. There is no means of making an accurate estimate of the average weight rolled in 1880, but 67 lbs. per yard may be taken as the maximum of that date, while 56 lbs. was a very common weight.

Rail Fastenings.—In rail fastenings little progress has been made. Many rail joints have been contrived, but nothing has superseded the angle bar, or seems likely to, although this is admittedly defective. The plain fish plate has disappeared from good practice in the United States. Even the best length of the angle bar is still in dispute, as is the question of supported and suspended joints. If after many years of trial, it cannot be decided whether or not the contiguous rail ends should be supported on a tie or suspended between two ties; or what, between 24 in. and 48 in., is the best length of angle bar; it is very probable that there is not much difference in the results.

Within three or four years there has been an important advance in the use of metal plates on the ties, under the rails. Early in American practice, cast-iron chairs and plates were more or less used, even with the flange rail. It was found that the surface of the head of the rail was worn directly over the chair, from the fact that the greater mass of metal just at that point made the blow of the wheel more efficient. This experience has retarded the use of tie-plates, desirable as they are to save ties and to prevent rails turning or spreading. Recently, however, plates of steel have been introduced. These give all the advantages of increased bearing on the tie, and utilize the whole holding power of the inside spike against the outward thrust, and are still light enough and elastic enough to avoid the anvil effect of the more massive cast-iron chair. Practically the only changes in track spikes have been in the methods of manufacture and in the material. Recent machines turn out spikes with points that make a clean cut when driven, greatly reducing the destruction and the displacement of the fibers of the tie. The result is increased holding power and longer life of the tie. Many spikes are now made of steel. In England and on the continent of Europe the general practice is to use screws instead of spikes to hold the rails to the ties, and to use cast-iron chairs with bull-head and double-head rails. With flange rails tie-plates are sometimes used, but oftener the rail rests directly on the tie.

Ties.—In the United States, the wooden cross-tie not only remains standard, but the trials of metal ties have been quite insignificant in extent. Considerations of economy and of adaptability to the purpose indicate that there will not be any large use of metal ties in this country until the means of preserving wooden ties and the benefits of tie-plates have been exhausted. The wooden tie, so long as it does not cost too much, has great advantages of elasticity and of convenience in track work. In Europe, India, South America and various colonies, the use of metal ties has been much more extensive, and a great variety of designs have been brought out and tried. The best results have been got with a cross-tie of steel, in the form of a channel, laid with the hollow down, and with the ends bent down to engage in the ballast. Of this type, the tie designed by Mr. Post, engineer of the Netherlands State Railroads, is the best known. The designs are so many, and the results so varied and inconclusive, that it would take too much space to properly discuss the subject here. The most complete *résumé* is contained in Bulletin No. 4, U. S. Department of Agriculture, 1890.

Railway Head: see Cotton-spinning Machines.

Raker, Hay: see Hay Carriers and Rakers.

Ram, Hydraulic: see Engines, Hydraulic.

Reamer: see Lathe Tools.

Reaper: see Mowers and Reapers.

REAPERS. The reaper has been so far superseded by the binding-harvester that inventive energy may almost be said to have become diverted from this form of harvesting machine; nevertheless a large aggregate of reapers is made annually. Steel, and malleable and cast iron are employed for many of the parts before made of wood. In reapers, as in the case of mowers, the front-cut construction has been adopted, bringing the cutter-bar forward on a line with the front of the machine, instead of the former rear-cut construction, to get the driver back to a safe position out of the danger, formerly incurred, of a fall in front of the sickle.

Wood's Reaper.—A front view of an improved reaper, by Wood, appears in Fig. 1.

It has a novel rake-controlling device. The rake arms, which, in this class of machine also serve to reel the standing grain to the sickle, and lay it on the triangular platform, are guided in their sweep by the ordinary cam track, but this track contains a switch, the automatic movements of which direct any given rake arm upward to clear the platform in passing around the rake-head axis, or downward to sweep from the platform to the ground the grain accumulated thereon. Fig. 2 shows the controller parts shaded. The controller finger is set to switch every second rake to sweep the platform ; and Fig. 3 shows the finger forced up by a revolving spiral inclined plane until it trips the cam switch which decides the course to be followed by a rake arm, and then drops back to the same level from which it started. The driver, without halting, sets the finger by the hand lever and index to drop upon either of the spiral ledges, after which it continues to open the switch automatically, at the exact intervals

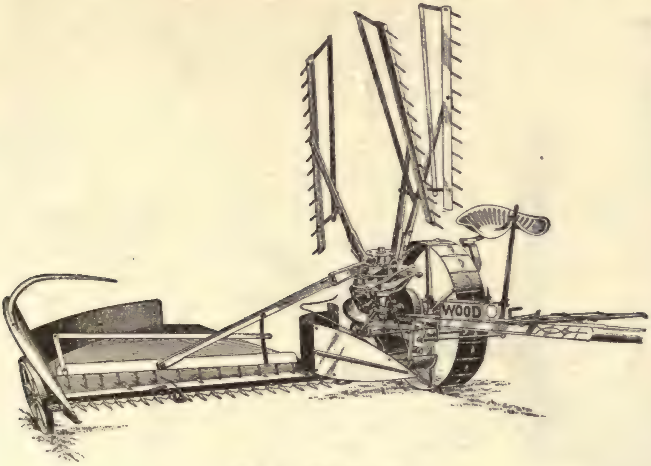


Fig. 1.—Wood's reaper.

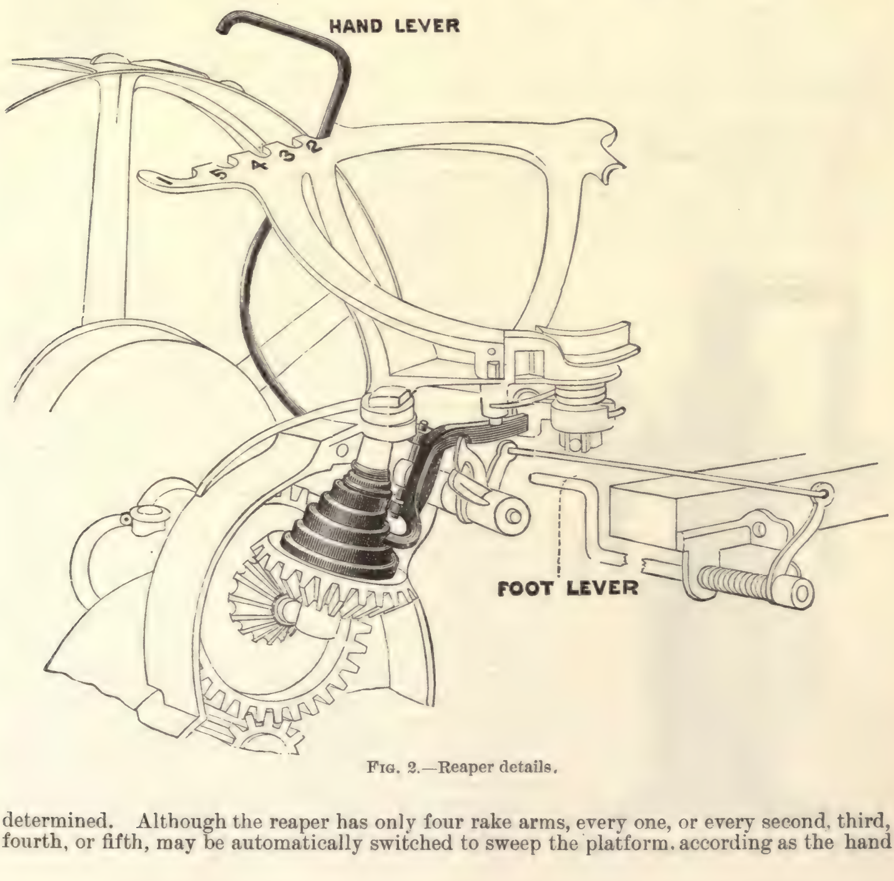


Fig. 2.—Reaper details.

determined. Although the reaper has only four rake arms, every one, or every second, third, fourth, or fifth, may be automatically switched to sweep the platform according as the hand

lever is moved on the numbered index. A foot lever, seen in Fig. 2, serves to interrupt the operation of the automatic controller, when the driver prefers to momentarily cease raking off, though the movement of the rake arms as reels continues to direct the standing grain to

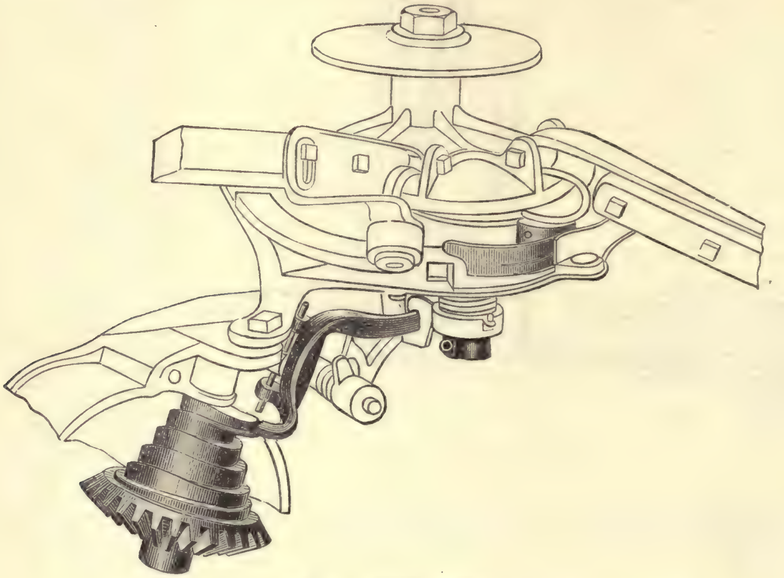


FIG. 3.—Reaper.—Detail.

sickle and platform. This is done in specially thin spots in the crop, and at corners to avoid dropping sheaves there, where the team would on the next round trample them and waste grain.

Reel: see Milling Machinery, Grain and Cotton-spinning Machines.

Refrigerating Machinery: see Ice-making Machines.

REGULATORS. I. DAMPER REGULATORS.—*The Mason Steam Damper Regulator* is shown in Fig. 1. It is designed to automatically maintain any desired pressure in a steam boiler by controlling the draft. The operation of the regulator is as follows: The boiler pressure, which is connected at the pipe, *G*, comes into the chamber, *E*, the top of which is formed by a diaphragm, on which rests the main spring, *S*. If the boiler pressure rises above the required point, or sufficiently to overcome the tension of the spring, *S*, the diaphragm is raised very slightly and the steam passes down the passage, *X*, to the upper surface of the piston, *D*, which it forces down. This piston being connected with the wheel on the shaft, *H*, by a chain, or rack and pinion, turns it around, communicating a like motion to the outside wheel, and thence to the damper in the flue.

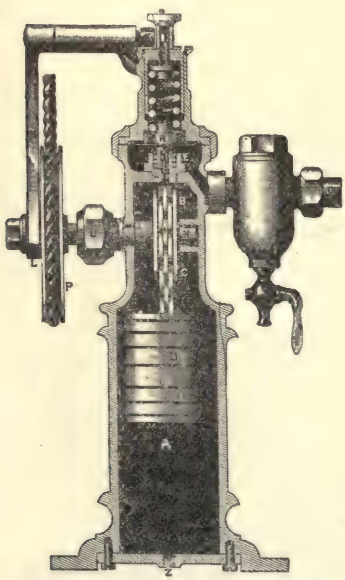


FIG. 1.—Mason damper regulator.

When the boiler pressure falls, the diaphragm comes on to its seat, which covers the passage, *X*, and steam pressure is removed from the top of the piston, *D*, while the weight on the damper brings the wheel, *P*, back to its original position.

Kellam's Steam Damper Regulator is shown in Fig. 2. The instrument consists of a piston, *Y*, upon which is a projecting ground-joint, *W*, containing water-packing grooves, upon which works an accurately fitted cylinder, *K*, which is in turn covered by a sleeve, *C* (weighing from 12 to 50 lbs., according to the size of the machine). To the bottom of the piston is screwed the section, *U*, in which is fitted the valve, *V*, on a raised seat. Upon this valve rests the stem, *P*, the top of this stem bearing against the weighted lever, *F*. The operation is as follows: The weight, *I* (from $1\frac{1}{4}$ to $2\frac{1}{2}$ lbs.), is adjusted on

lever, F, so that the valve, V, will open at the pressure which it is desired to carry on the boiler when the steam entering ports, Q, passes through the piston, Y, raising the cylinder gradually till cap, L, comes in contact with the bottom of ground-joint, W, at which time the damper is entirely closed. As the boiler pressure lowers, valve, V, is pressed to its seat by weighted lever, F, and as the condensation passes from within the piston through the pet-cock, E, the cylinder descends, drawing the damper open.

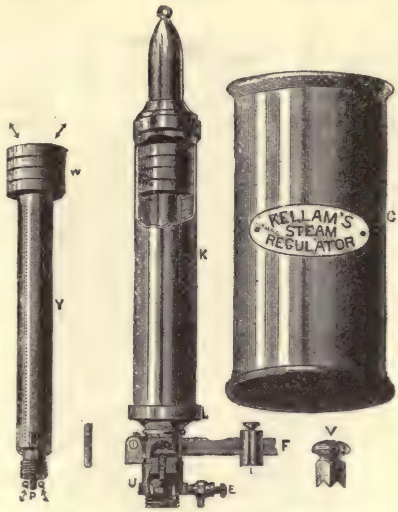


FIG. 2.—Kellam's damper regulator.

The Curtis Damper Regulator is shown in Fig. 3. It consists of a composition cylinder, within which is a piston fitted with water packing. The piston-rod is connected by a chain, over guide rolls, to the lever of the damper, on which is hung a weight sufficient to overhaul the piston and open the damper regardless of any ordinary friction. The motion of the piston is controlled by a metallic diaphragm, which operates the valve, alternately closing and opening the damper as the boiler pressure increases or diminishes. The regulator is fastened to the wall of the boiler-room; the top pipe is connected to the boiler, and the lower pipe to the drain, ash-pit, or heater. The normal condition of the damper is to be wide open, the weight holding it in that position. To operate it, a given load—say 60 lbs. to the inch—is produced on the regulator diaphragm, by screwing the handle in. When the pressure in the boiler reaches 60 lbs., it lifts this load and permits steam to enter the space over the piston, slowly pushing it down and closing the damper. When the boiler pressure falls below 60 lbs. the valve closes, and the pressure, passing from the top to the bottom of the piston, puts the piston in equilibrium, and allows the weight, slowly settling down, to open the damper, thus controlling the pressure at the desired limit.

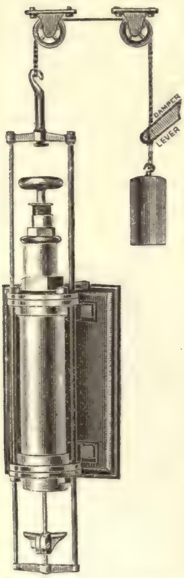


FIG. 3.—Curtis damper regulator.

II. PRESSURE REGULATORS.—*The Foster Pressure-regulating and Reducing Valve* is shown in Fig. 4. The principle of operation is as follows: Steam is admitted at A and delivered at B, at a pressure dependent upon the opening of valve, D, which may be regulated by turning spindle, P, to the right to diminish the pressure, or the left to increase the pressure. The delivery pressure, entering chamber, K, tends to raise the diaphragm, W, and draw valve, D, toward its seat; in opposition to this, the spring, with its lower end bearing on winged nut, E, tends to open the valve until there is an equilibrium established between these two forces. Under this condition, if the delivery pressure fails, the pressure on the diaphragm is diminished, and the spring, overcoming the lighter resistance, opens the valve until the equilibrium is again established and the pressure restored; on the other hand, any increased delivery pressure bearing on the diaphragm overcomes the resistance of the spring and draws the valve toward its seat in proportion to the increased pressure. When the tension of the spring is proportioned to the pressure bearing on the diaphragm, a constant and uniform discharge is insured. The spring nut, E, is threaded on the spindle, and, having wings which extend into the hexagon spring chamber, H, it is prevented from turning with the spindle, but is free to move longitudinally with it, as the valve is opened or closed by reason of variation of pressure on the diaphragm. The flange on lower side of spring nut, E, is used as a stop to prevent an excessive lift and possible bulge of the diaphragm.

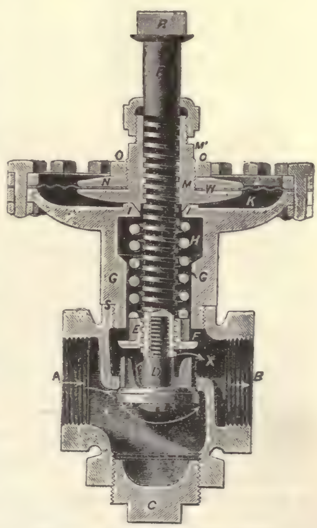


FIG. 4.—Foster reducing valve.

The Ross Pressure-regulating Valve is shown in Fig. 5. It is used to control or reduce pressure in street mains and pipe lines; or to regulate the flow of water between reservoirs located at different levels. In the sectional view, A is the inler to

high-pressure side; *B*, the outlet or low-pressure side. The operation of this valve is as follows: The small regulator valve, *I*, has been set to close at, say, 40 lbs.; relief valve, *O*, to open at as nearly as possible the same pressure. This can be readily adjusted when the valve is working. It is preferable to have relief valve, *O*, open a little in advance of the closing of the regulating valve, as this keeps a circulation constantly through the chamber, *K*, and valve, *I* and *O*. This maintains a very even pressure in the chamber, *K*. The pressure in chamber, *K*, determines the pressure on outlet side of valve, *B*. For illustration, assume that piston, *D*, is one-half the area of *F*. (It can be more or less, as desired; the practice is to make it less.) Water is turned on the system, and passes freely through the valve until the pressure, accumulating in the pipes on the outlet side, is exerted on the full area of the valve beneath *M*. When 20 lbs. is reached an equilibrium exists, and any further rise of pressure at *B* will increase the pressure twice as much in chamber, *K*. This decreases the flow of water through *I*, and increases the quantity discharged through *O*, allowing the pistons, *F* and *T*, with valve, *M*, to slowly close until only enough water passes to maintain 20 lbs. pressure at outlet *B*. Should an extra demand on the system cause the pressure to fall below 20 lbs. on the outlet side, *B*, relief valve, *O*, would close and regulating valve, *I*, would open, thus allowing pistons, *F* and *T*, with valve, *M*, to open, and allowing sufficient water to pass to keep the pressure at 20 lbs. Any rise or fall of pressure will continue to repeat this operation.

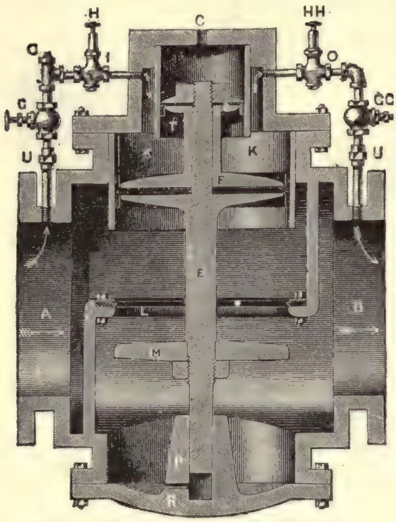


FIG. 5.—Ross pressure-regulating valve.

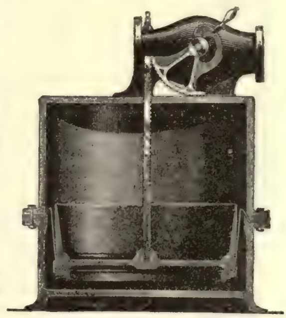


FIG. 6.—Union regulator. Detail.

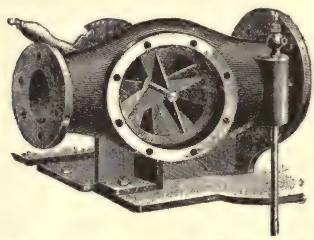


FIG. 7.—Union gas pressure regulator.

The Union Gas Pressure Regulator, made by the Union Water Meter Co., Worcester, Mass., is shown in Figs. 6, 7, and 8. It is built on the tank or gasometer principle. Fig. 6 is a sectional view of the tank and piston connected with the valve by rack and segment. Fig. 7 is a view of the valve with cap removed, showing the valve-stem and V-shaped ports. Fig. 8 shows the valve-stem detached from the valve with the four ports which open and close over four alternate parts in the valve-seat. The operation is as follows: The gas is taken from the low-pressure side of the valve by the pipe, shown in Fig. 7, to the under side of piston in the diaphragm case in Fig. 6. Then any increase of pressure immediately raises the piston and closes the rotary valve by means of the rack, *A*, and segment, *F*; any decrease of pressure opens the valve. The rotary valve with V-shaped ports is operated by a piston with a rolling diaphragm, thus giving a long stroke and graduating the flow of gas with the greatest accuracy. The conical form of valve admits of its being ground to a gas-tight joint, not affected by contraction or expansion, and requiring no packing around the valve-stem. The ports have cutting edges and a shearing motion, thus effectually preventing the formation of ice or the accumulation of foreign matter on the valve seats, which so often prevents the closing of other forms of valves. By the rotary motion of the valve, and its opening and closing both ways from the center, a positive cut-off is effected

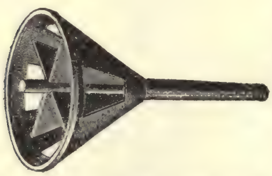


FIG. 8.—Union regulator. Detail.

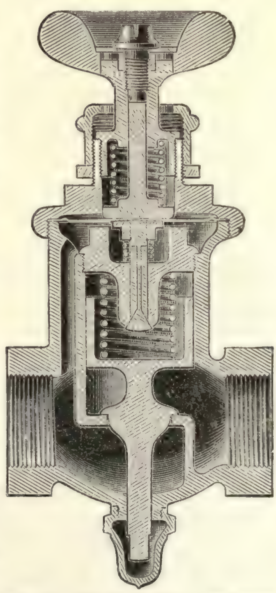


FIG. 9.—Curtis pressure regulator

without extra mechanism, the weight of the piston closing the valve whenever the supply of gas fails. Nor can any leak around the piston or diaphragm, or increased pressure of gas, force the valve open and allow the gas to blow through.

The Curtis Pressure Regulator, made by the Curtis Regulator Co., of Boston, shown in Fig. 9, has a main valve, operated by a loose-fitting piston ; a secondary valve in the top of the chamber over the piston ; a metallic diaphragm (performing the double office of operating the secondary valve, and making a joint to the cap which contains it); and a side passage, connecting the chamber under the diaphragm with the outlet. When the spring over the diaphragm is compressed, it opens the secondary valve upon which it rests. Pressure being let on. raises the piston, and therewith the main valve to its full capacity. The main valve remains open until the back pressure communicated from the outlet throughout the side passage is sufficient to raise the follower under spring, and thus close the secondary valve, when the steam or water escaping around or through the loose-fitting piston fills in the space on top of said piston, and forces it toward its seat, thus uniformly maintaining the pressure at which it is set.

Repeating Rifle : see Fire-arms.

Re-sawing Machines : see Saws, Wood.

Revolvers : see Fire Arms.

Rifle : see Fire Arms.

Rim Planer : see Wheel-making Machines.

Riveting, Electric : see Welding, Electric.

RIVETING MACHINES. *Elastic Rotary-blow Riveting Machine.*—The use of the machine shown in Fig. 1—made by John Adt & Son, New Haven, Conn.—extends to almost every branch of manufacturing where articles are held together by rivets. Its most important feature is in the combination and working of the cylinder and hammer-rod. The hammer-rod, suspended by springs and confined air within the cylinder, partakes of its reciprocating motion, and produces a sharp, quick blow, which, with its rotating action, enables the machine to perform the

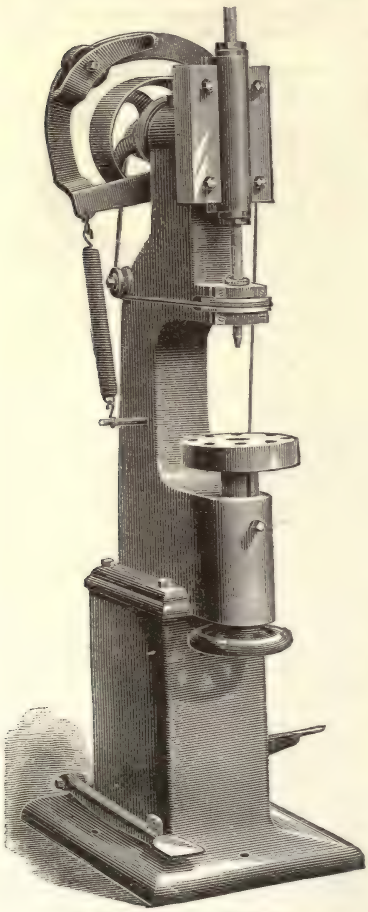


Fig. 1.—Riveting machine.

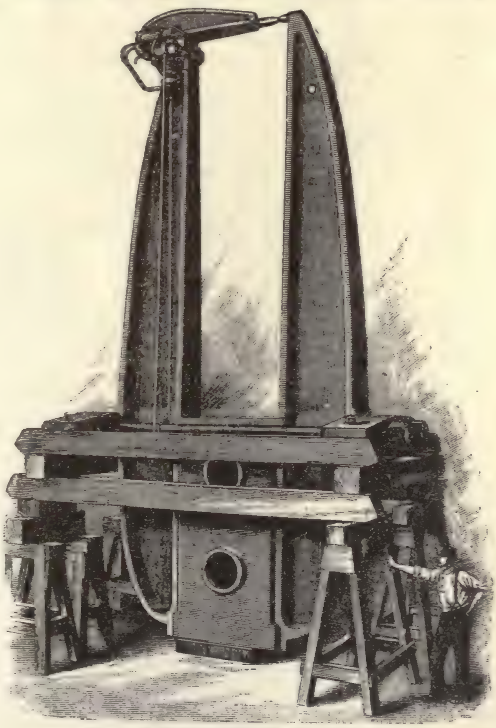


Fig. 2.—Hydraulic riveting machine.

work almost instantly. The blow is rendered elastic by the springs in connection with the air cushions, and its force can be regulated at the will of the operator by more or less pressure applied to the treadle at the right of the machine ; the yoke to which the treadle is attached is self-acting, and the moment the pressure is removed the blows cease, and the work can be withdrawn.

The hammer always strikes on the rivet, heading it equally, and as it is rotated while the blows are being struck, the head conforms to the shape of the peen of the hammer, and any style of head can be formed.

Riveting Machine, Hydraulic.—The riveting machine shown in Fig. 2 was designed and built by William Sellers & Co., of Philadelphia. It has a gap of 198 in. measured from the center of the riveting dies to the base of the throat, and the distance between the frames or stakes is 4 ft. 6 in. The ram is operated by hydraulic pressure, and is capable of exerting variable pressures of 25, 50, or 75 tons upon the rivet, at the will of the operator, from a fixed accumulator pressure of 2,000 lbs. per sq. in. These variations are obtained directly at the machine itself by a valve of special construction, and by the simple movement of a single lever conveniently located. The stakes are of cast-steel, and the requisite spread is obtained by means of the massive cast-iron box at the base, the whole being securely tied together by the large through bolts shown. The cylinder is also of cast-steel, and has cast with it the bearing for the riveting ram, which bearing is necessarily prolonged by the large overreach. The machine, instead of being placed in a pit, as is frequently the case, so as to make the floor line form the working platform, is set with the bottom of the throat level with the shop floor, and a platform (not shown) is attached to the main stake about 3 ft. below the center of the ram, so as to bring the operators at the most convenient distance to the dies.

ROD-MAKING MACHINERY.—For making rods and dowels there is ordinarily employed a hollow arbor, having a head and cutters revolving about the rod, cutting it smooth and true. Rolls back of the cutter-head drive the material into the machine; these rolls having grooves made to fit the thinnest size of the rods, and being fastened to the shaft by set-screws, so that in working the rolls are moved sidewise to bring the right sized groove for the rod to be worked exactly in the center. In the latest machine the feeding arbor is vertical and center, the stock being turned.

Roller : see Seeders and Drills.

Roller Mills : see Ore-crushing Machines.

Rolling Machinery : see Leather-working Machinery.

Rolls : see Coal Breakers, Milling Machinery, Grain and Ore-crushing Machines.

ROLLS, BENDING. *Heavy Plate-bending Rolls.*—The full-page illustration, Fig. 1, represents the No. 12 power bending rolls made by the Niles Tool Works, Hamilton, O., for bending plates up to 2 in. in thickness. This machine is 22½ ft. between the housings, and has four wrought-iron forged rolls, 22½ ft. long between the journals.

The two feeding rolls are placed vertically one over the other, and are 32 in. in diameter, and the two bending rolls are placed one on each side of the center rolls. These are 25½ in. in diameter, and move in guides in the housings. They are so placed as to move very closely by the lower center roll when the latter is touching the upper roll. The upper feed roll runs in fixed bearings in the housing, and the lower roll runs in bearings having a vertical adjustment of 5 in., obtained by means of heavy steel adjusting screws 8 in. in diameter, operated by tangent gearing.

The bending rolls have an adjustment of 20 in. When in their lowest position the upper surface is 4 in. below the bottom of the upper feed roll, from which position they move upward until they touch the upper feed roll. The adjusting screws for these rolls are of steel, 7 in. in diameter, and are operated by tangent gearing. The two bending rolls and the lower feed roll are raised and lowered by a pair of reversing engines, which are used for this purpose only. Clutches are provided in the train of elevating gear for all the movable rolls, so that either one or both ends of any of them can be moved independently. Safety friction clutches are provided in the gear train of the lower feed roll, which allow the gearing to slip when the feed rolls and plate are pressed tightly together. Graduated index scales are provided to indicate the exact height of the ends of the rolls.

The two feed rolls are positively geared together from opposite ends. The main gear on each roll is 10 ft. diameter, 15 in. face, and 5 in. pitch. They are driven by a pair of reversing engines, whose cylinders are 12 in. diameter, and stroke 16 in. The machine is mounted on a heavy cast-iron sole plate, 18 in. deep, bedded in a massive stone foundation, and sunk to a level of 7 ft. below the floor line. The plates are intended to pass through the rolls at a height of 19 in. above the floor. The reverse levers and throttles for the engines are operated from one common platform, erected on the sole plate, level with the floor, and all clutch and operating levers are brought to a convenient position above the floor.

Vertical Plate-bending Rolls.—Fig. 2 illustrates a vertical plate-bending machine, built by Thomas Shanks & Co., Johnstone, Scotland, which is capable of bending cold steel plates 1½ in. thick, and 12 ft. 6 in. wide. The front roller is of steel, 23 in. in diameter, and is adjustable to and from the inner rollers, which are 16 in. in diameter, of forged steel. The adjustment is by two screws driven by worm-wheels and vertical worm-shaft, with bevel gear worked from either side of the machine. The forged iron nuts of the screws form the slide and bearings which carry the journals of the front roller. The machine rests on four cast-iron stools, to which is bolted a strong frame carrying one end of the pinion shaft, containing two bearings for the back rollers, and a parallel space for the sliding block of the front roller. To this plate is also bolted a gearing frame, with the bearing for the cross-shaft and bevel pinion. These plates, with the four stools, are bolted to the masonry foundation. The top framing, carrying the rollers at the top, as also the top main pinion shaft, is cast-iron, and it is supported on a massive vertical standard, checked and bolted to the sole plates, and this forms a rigid frame to self-contain the strains. It is cast with bearings for the anti-

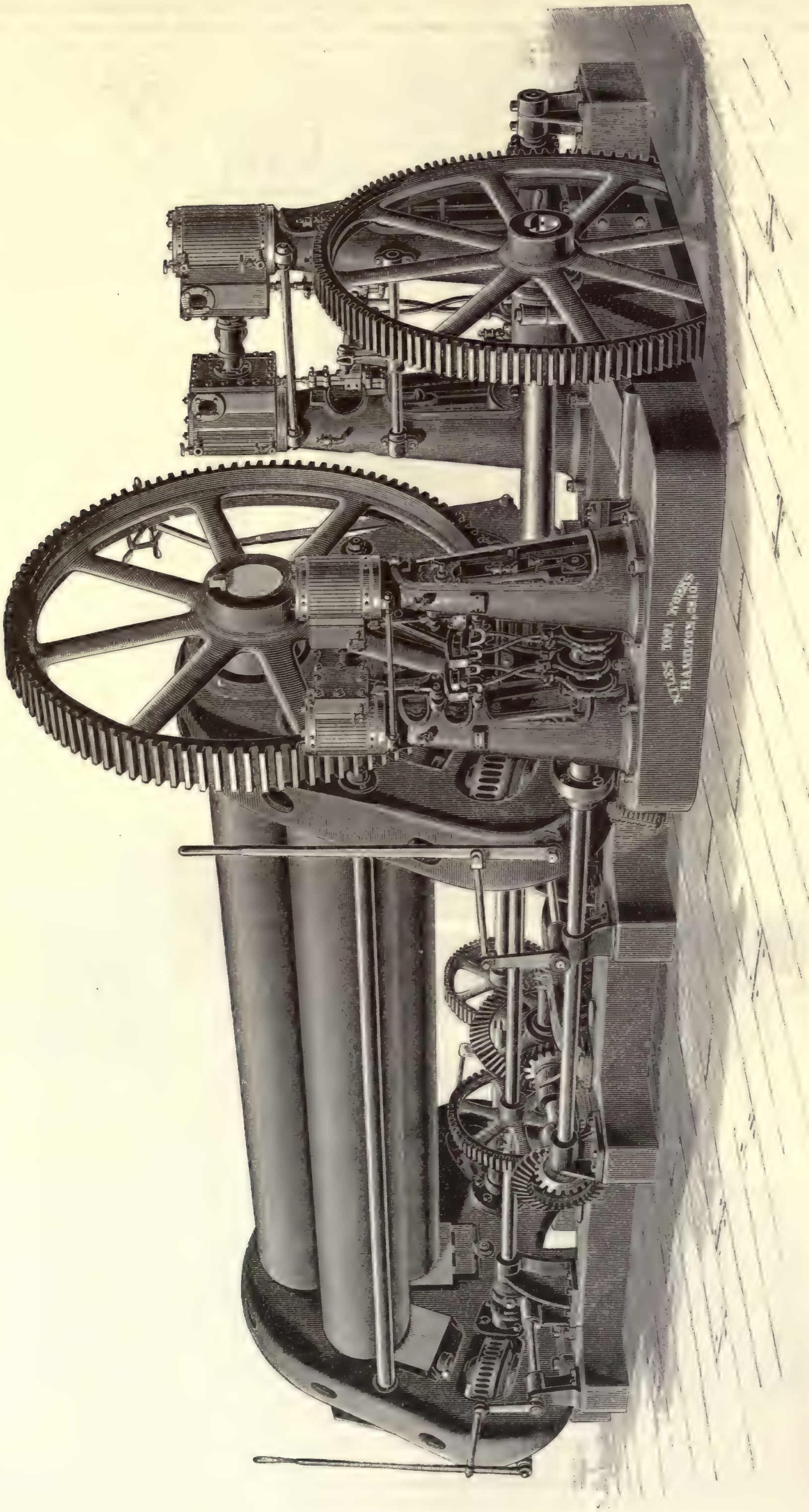


FIG. 1.—Niles power bending rolls, with engines.

friction rollers. These are 12 in. broad, those at the sides being 10 in. in diameter, and at the back 18 in. in diameter. They are so arranged that they transfer the pressure off the roller to the vertical standard. The inner rollers are each driven by a large spur-wheel, $3\frac{1}{2}$ in. pitch, worked by pinions, keyed to the connecting shaft, 8 in. in diameter, upon which also is keyed the large bevel wheel. Spur-wheels and pinions enable the gearing to be altered for heavy or light work. The engines for driving the machine are of the vertical type, having 12 in. cylinders.

Sellers' Bending Rolls.—Fig. 3 shows a set of vertical bending rolls, built by William Sellers & Co., of Philadelphia, which are capable of bending a steel plate 10 ft. wide, $1\frac{1}{2}$ in. thick. The bending roll, 18 in. diameter, and the two side rolls, 15 in. diameter, are carried in heavy plate housings, and so united as to embody great strength, and at the same time leave the front of the machine unobstructed for the free curvature of the plate. All three rolls are driven by a pair of independent reversing engines. The bending roll is the principal driving roll, and the side rolls are adjustable to and from the bending roll by another

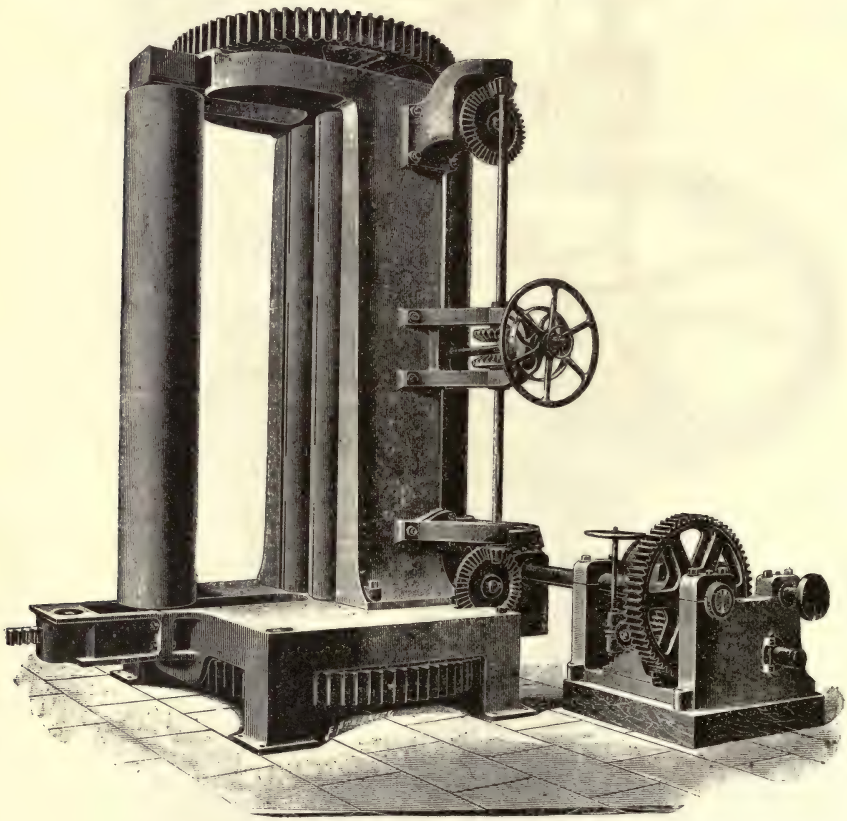


FIG. 2.—Vertical plate-bending rolls.

pair of independent engines, controlled by convenient levers, and so arranged that the two ends of the rolls may be adjusted together or independently in either direction. The driving wheels at the bottom of the side rolls are of steel, while the bending roll carries at its upper end a spur-gear wheel over 5 ft. in diameter, and about 4 in. pitch by 11 in. face, driven by a steel pinion. The bending roll, with its upper bearing and driving wheel, can be withdrawn by an overhead crane for the removal of flues. Hitherto the problem of driving all the rolls at the same peripheral speed has been embarrassed by the calendering action developed in the passage of a curved plate. To avoid this action, and at the same time relieve the driving gear of unnecessary strain, there is provided in the train of gearing for the side rolls a positive clutch with sufficient lost motion to allow for the maximum effect of calendering. The work of driving the plate through the rolls is thus thrown chiefly on the gearing, which drives the middle roll, and although the pinions on the side roll are thus relieved of the work of driving, they are always in readiness to assist, should the friction of the middle roll on the plate be insufficient to carry it through.

The Niles Plate-straightening Machine, shown in Fig. 4, is designed for straightening plate iron for boilers, tanks, safes, etc. It has seven rolls arranged in two tiers—four rolls

in the upper tier, and three in the lower. The lower rolls are driven by steel pinions. The upper series of four rolls are adjustable vertically to suit the thickness of sheet to be straight-

FIG. 3.—The Sellers bending rolls.

ened. Indexes are provided for setting these rolls. The outer rolls of this series are adjustable independently ; the inner rolls are raised or lowered together, and the entire four

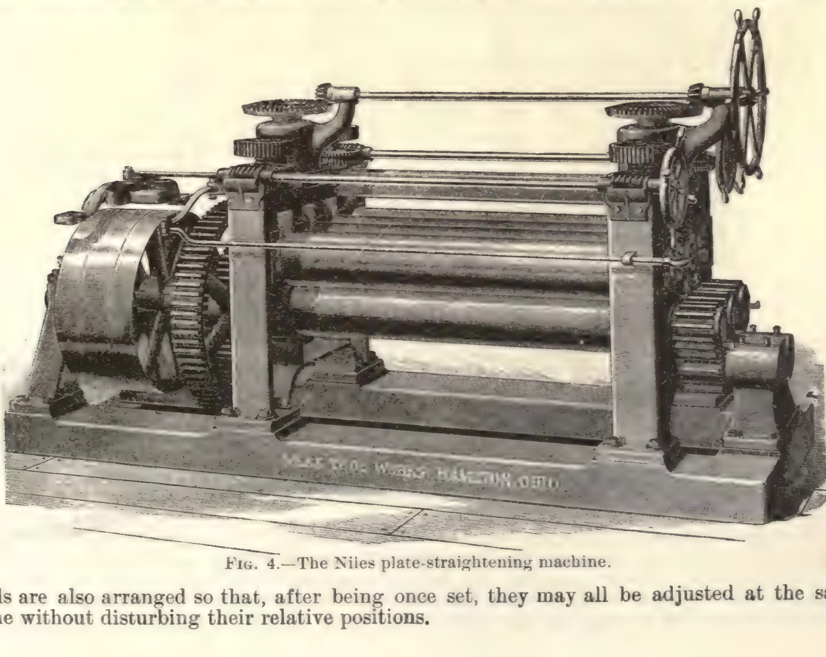


FIG. 4.—The Niles plate-straightening machine.

rolls are also arranged so that, after being once set, they may all be adjusted at the same time without disturbing their relative positions.

ROLLS, METAL WORKING. *Roughing Train and Doubling Machine for a Tin-plate Rolling Mill.* — Theodore L. Thomas, of the Union Works of the Illinois Steel Co., Chicago, has designed a mill for rolling tin-plate bars, which is herewith illustrated, Fig. 1 showing the side elevation, and Fig. 2 the ground plan. Mr. Thomas has also devised a doubling machine, likewise shown in the illustrations, which is an important part of the apparatus. This mill is intended to break down tin-plate bars and prepare them for the usual finishing train. It consists of three sets of rolls, three high, inclosed in one pair of housings and driven by one engine, as indicated by the gearing. The doubling machine consists of four folding-doors lying at floor level, with shears in the center.

In the usual method of making sheets for the tinning process, the practice followed is to

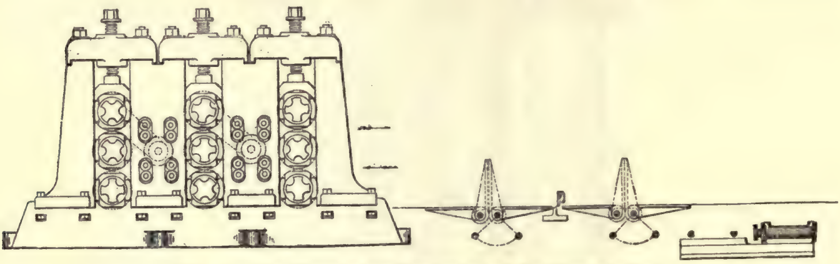


FIG. 1.—The Thomas roughing train and doubling machine.

take a 7-in. bar, cut to suitable width, which is subjected to five heatings and five rollings, with four doublings. The five rollings are known to millmen as (1) molding, (2) singling, (3) doubling, (4) fours, (5) eights, finishing to suitable lengths. The description applies to what is known in the market as IC 20 x 14. By Mr. Thomas's method a 14-in. bar is taken. It is heated, passed through the lower rolls in the direction of the arrow, shown in Fig. 1, and then back through the upper rolls. The rolls are adjusted by lining, graduating the work on the bar throughout the six passes. Guide rollers between the rolls keep the bar in proper position for the next rolls. The rolls are a sufficient distance apart to prevent buckling. The sheet which emerges from the last pass is trailed on the floor a little on one side of the doubling machine. It is then pushed by machinery on the folding-doors and into the shears, which cut it in two. The doors next move into a perpendicular

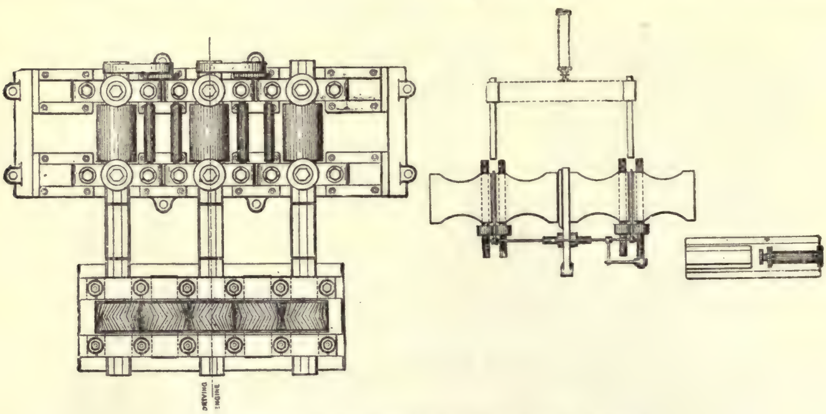


FIG. 2.—The Thomas roughing train and doubling machine.

position, thus doubling the two sheets at one operation and one heat. The doubling machine is operated by hydraulic or steam cylinders.

Two-fifths of the work of rolling the black sheets is performed at this stage, leaving three-fifths to be done in the finishing mill, to which the doubled sheets are taken by an endless chain or other labor-saving device. The finishing mill being thus relieved of two-fifths of the work of rolling the black sheets, can be operated with much greater capacity than by the old method.

The Simonds Metal Rolling Machine.—A novel machine for the rolling of special shapes of metals, built by the Simonds Rolling Machine Co., of Fitchburg, Mass., is shown in Fig. 3. The machine is designed for rolling accurately and in a short space of time a large variety of work which at present is turned out by more laborious and expensive processes, such as lathe turning, the customary methods of forging, and others. The machine

consists in the main of a substantial bed and two standards, which are practically duplicated within and below the frame and floor line, as shown in Fig. 4. Mounted on these standards

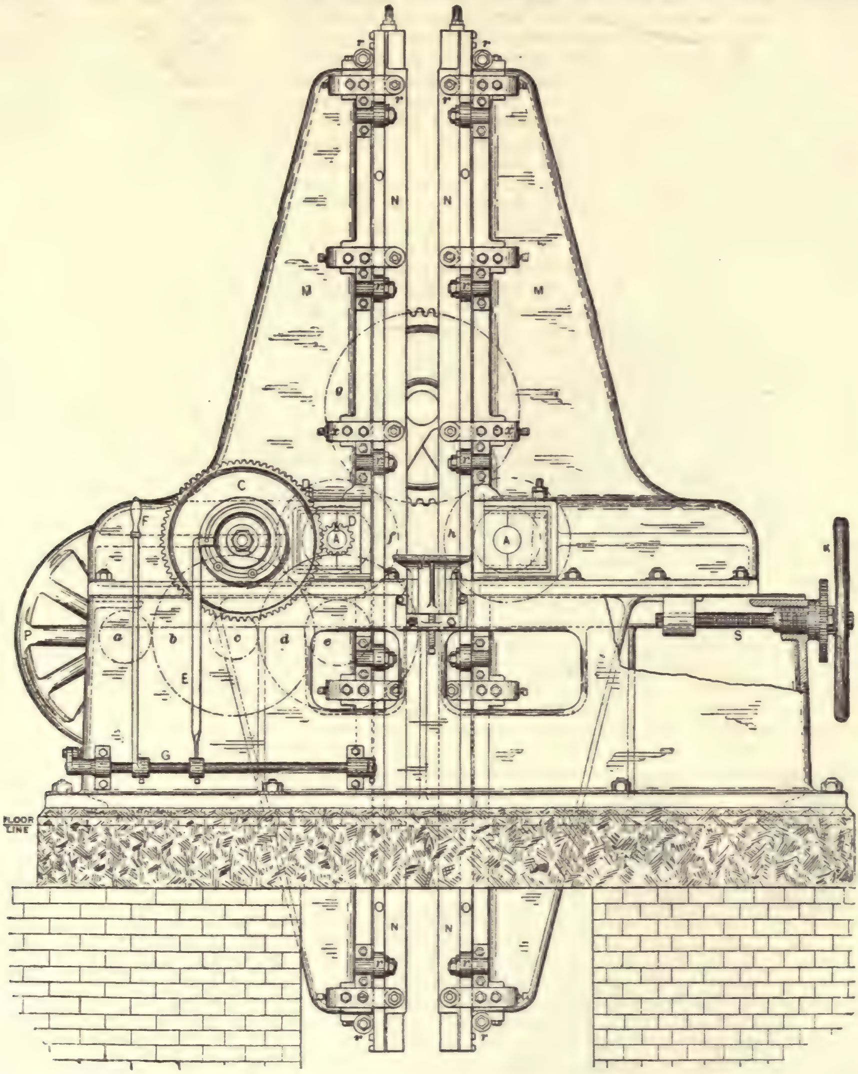


FIG. 3.—The Simonds metal rolling machine.

by means of suitable fixtures, are a number of rollers, arranged to act as front, rear, and side supports and guides to cast-iron traveling platens, O O. They thus take the place of the ordinary sliding surfaces, and, affording only rolling contact, reduce friction. Fitted into the backs of these platens are racks which engage with suitable mechanism, so that one of the platens always travels upward, while the other travels downward.

The platens, O O, carry iron plates, into which the dies proper are dovetailed, the section

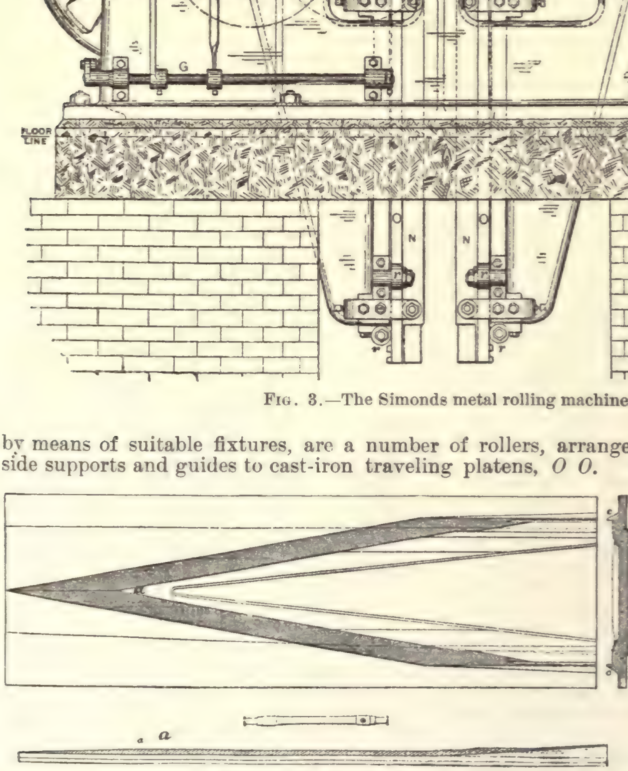


FIG. 4.—Die for car axle.

of these for this purpose being as shown in Fig. 4. The die there illustrated is for forging car axles, of one of which a sketch is also given. The dies are used in pairs, moved in opposite directions over the metal to be shaped, the die surfaces, of course, being exactly alike. From the plane faces of the dies, which lie parallel to each other when in position for work, rise the forming and reducing and spreading surfaces, the plane portions serving to support and steady the work and prevent it from rocking. The reducing surfaces are grooved or serrated, in order to insure a firm grip on the hot and plastic metal, and perfect regularity in its rotation, and being thus arranged obliquely, the marks made in the metal by the serrations are obliterated in subsequent revolutions of the blank, and the rate of the surface movement of the latter, where work is being performed, is the same as the rate of linear movement of the dies. The reducing faces commence to work on the metal at the extreme left, where they meet in a point, and when the hot blank is placed between the dies, the central reduction of the axle is commenced by the narrow end of the tapering raised portion, *a*, of the die face. In general configuration, the raised portions are like the half section of the axle, the shearing off squarely of the ends of the axle being accomplished by the level edge cutters, *c c*. The edges of these cutter projections are also serrated, so that the rotation of the blank is under control throughout the length of travel of the die. The material operated upon is compressed and condensed as it assumes the required shape under the dies. The construction and function of all other forms of dies for use in the machine are on the same general basis.

The blank to be operated upon is inserted between the dies, and rests on the supporting plate marked *V*, in Fig. 3, one of the dies being at or near the end of its up stroke, and the other at or near the end of its down stroke, so that the extreme ends of the gripping surfaces of the dies are opposite each other in a line passing through the centers of the shafts, *A A*. One of the die platens travels up and the other down, until the extremities of the cutting-off edges are opposite each other, when a finished car-axle, or whatever other product the dies may have been designed for, is the result. The whole operation occupies only a fraction of a minute. The smaller the article made, the greater may, of course, be the speed of working; boot calks for lumbermen, for example, being turned out at the works of the Simonds Rolling Machine Co. at the rate of from 10,000 to 20,000 per day.

The Munton Process of manufacturing Steel Tires.—The Chicago Tire and Spring Co., of Melrose, near Chicago, Ill., use a plant for the manufacture of locomotive and car-wheel tires and circular forgings which, in its method of treating steel, is a marked departure. Mr. James Munton, the superintendent, is the inventor of the new process and the machinery for operating it. The ordinary method of manufacturing tires is to cast a solid ingot of cylindrical shape, which is then heated and upset under a steam-hammer until its height is reduced and its diameter enlarged. After a hole has been punched in its center, the ingot is then placed on a beak or pike-horn and hammered by blows struck on the periphery. It is then again heated and placed in a rolling mill, and rolled into a tire of the required diameter. In Mr. Munton's process he avoids the use of the hammer altogether, and in elongating the ingot, or bloom, into a tire he densifies the metal on the tread and increases the wear-resisting properties of the steel.

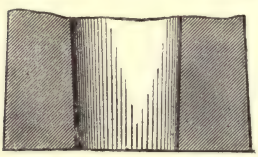


FIG. 5.—Ingot as cast.

A brief summary of the several steps taken is as follows: (1) The ingot is cast with a hole cored out large enough to admit a small roll. (2) The ingot is heated and taken to the rolling mill, where its top, with its imperfections, is sheared off and the bloom left of a given weight. At the same heat, and by the same operation, the bloom is also roughed out by the roughing rolls of the mill and edged down by horizontal rolls. (3) The bloom is reheated and placed in the tire rolling mill, where it is rolled and finished to the exact inside and outside diameter required. Mr. Munton's present practice is to cast an ingot large enough for two or more tire blooms. He uses a collapsible steel core. The steel is produced in an open-hearth furnace and poured from a ladle into the molds over a spreader of circular form, which covers the core and causes the steel to flow down on all sides, keeping any dirt in it flowing and thus collecting at the top. Fig. 5 shows a cross-section of an ingot as first cast, before slitting. Fig. 6 shows a two-tire ingot partially slit, and also indicates the method by which the slitting is done. In slitting, two upright rolls are used. One roll operates upon the inside of the ingot, as shown above, while the other roll operates on the outside. The outside roll is driven. It has a sharply beveled edge as a top cutter, a projecting flange as a central cutter, and a bottom flange to support the base of the ingot. Grooves are formed in this roll at suitable places to partly shape the tread of the tires. The flanges all extend the same distance outward from the roll. The inside roll has projecting flanges to

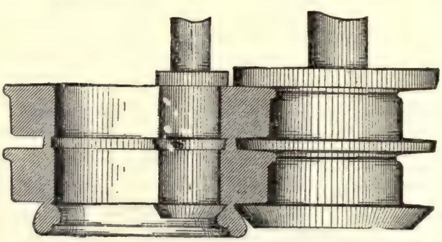


FIG. 6.—Ingot and slitting rolls.

correspond with those on the outside roll, but shorter. Fig. 7 shows an ingot after the top has been sheared off and the remainder cut into tire blooms ready for finishing. In Fig. 8 a perspective view of the mill is given. It consists of an exterior fixed vertical pressure roll (which also operates as the slitter); a vertical inner pressure roll, with horizontal movement; two vertical exterior pressure rolls with horizontal movement; and two horizontal or edging rolls, one above and the other below the bloom operated upon. The upper edging roll is moved vertically by the edging cylinder. This mill is a universal mill, which can be used for rolling tires or rings of any section and diameter up to 8 ft., and rings up to 16 in. wide. The vertical exterior pressure or slitting roll and the lower edging roll are driven by steam-power. The engine has no fly-wheels, being built on the reversing principle, so as to start or stop quickly. The movable

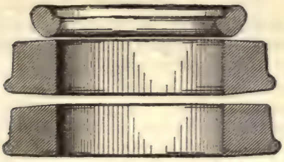


FIG. 7.—Ingot cut into tire blooms.

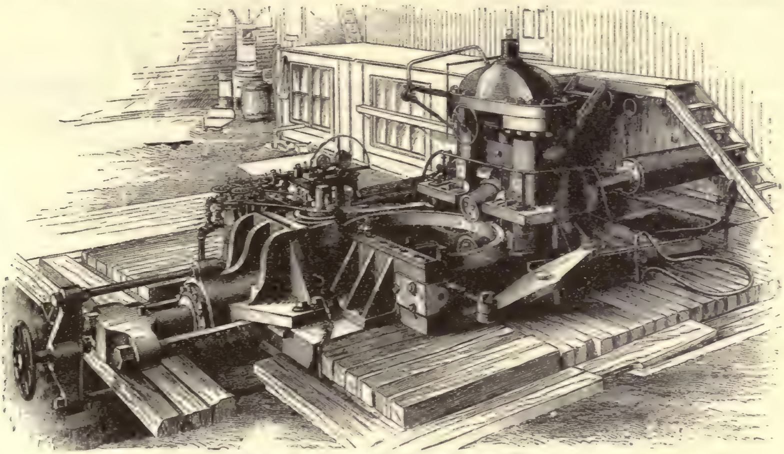


FIG. 8.—Munton's tire rolling mill.

rolls are operated by hydraulic power, controlled by valves shown in the foreground of the perspective view. Thus the edging, interior, or exterior rolls may either or all be brought into play upon the tire whenever desired, either simultaneously or one set at a time, so that the section of the tire, its size and diameter, are always under the complete control of the operator, and can be instantly changed as desired.

(For a more complete description of the Munton mill, see *Engineering*, October 17, 1890.)

Rolling Fluid Metal into Thin Sheets.—In 1846 Sir Henry Bessemer made some experiments on the manufacture of continuous sheets of glass, by passing the semi-fluid glass from a bath between a pair of rolls. On one occasion a sheet of glass 70 ft. long and 30 in. wide was produced, but the method was never brought into practical use. Ten years later, by somewhat similar means, he produced a sheet of iron, 3 or 4 ft. in length and $\frac{1}{30}$ in. thick, pouring the liquid metal

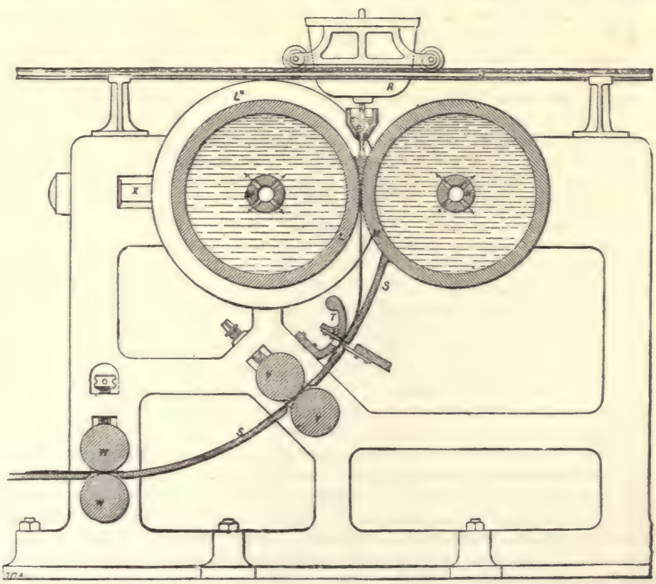


FIG. 9.—Rolling fluid metal.

onto a pair of rolls. He then obtained a patent on the process, but no commercial results followed. Experiments have recently been made in the United States on the same process, with such a degree of success that it has already been introduced as a commercial process. In 1891, forty-five years after his original experiments with glass, Sir Henry Bessemer read a paper before the Iron and Steel Institute of Great Britain, describing his proposed methods of remedying the defects of his first apparatus. From this paper (see *Engineering*, October 9, 1891), we abstract the following :

The rolls, *L* and *M*, Fig. 9, consist of two hollow drums through which a tubular steel axis, *N N*, passes, and conveys a plentiful supply of water for keeping the rolls cool. The brasses which support the roll, *M*, are fixed, while those which support the roll, *L*, are movable in a suitable slide, and are pressed on by a small hydraulic ram, which is in free and uninterrupted communication with an accumulator, so that at any time should the feed of metal be in excess, the roll, *L*, will move back and prevent any undue strain in the machinery, the only result being a slightly increased thickness at that part of the sheet of metal, a defect which, as it extends parallel across the whole width of the sheet, will be easily corrected in the next rolling operation. The rolls by preference may be made 3 ft. or 4 ft. in diameter, each having a flange on one end only, and thus form a trough with closed ends for containing the fluid metal. In order to obtain a regular and quiet supply of metal, I employ a small iron box or reservoir, Fig. 10, lined with plumbago or fire-clay; along the bottom of this reservoir some 10 or 20 small holes of about $\frac{1}{4}$ in. in diameter are neatly molded by a row of conical brass pegs. The reservoir is provided with a long bar or handle at each end. By means of these bars the reservoir is supported on the side frames, the bars falling into suitable notches made in the roll frame for that purpose. A pair of rails, *Q*, are supported on the roll frames, and serve for the conveyance of the ladle, *R*, which is mounted on wheels, and brings the metal direct to the rolls, or to any number of pairs of rolls that may be placed in line. The ladle is provided with one or more valves or stoppers of the usual kind, by means of which the supply of metal to the reservoir, *P*, may be easily regulated ; the several small streams from the reservoir will deliver an almost constant quantity of metal, varying only slightly as the operator regulates the head of metal in the reservoir. From the smallness of the head of metal in the reservoir the several streams will fall quietly without splashing. These streams do not fall direct onto the rolls, but into a small pool formed between the thin films solidifying against the cold surface of the rolls, the metal at all times being free from floating slags. The speed of the rolls also affords a means of regulating the quantity of metal retained between them ; and as a pair of 4-ft. rolls would only require to make about four revolutions per minute, a quick-running engine could easily be provided with differential speed gearing, so as instantly to alter the speed of the rolls to the very small extent ever required during the rolling process.

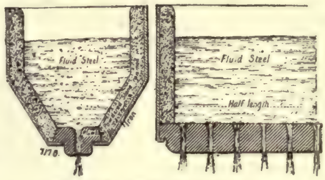


Fig. 10.—Metal reservoir.

The thin sheet of metal, as it emerges from the under side of the rolls, is received between the curved guide plates, *S* and *T*, to the latter of which a cutting blade, *U*, is bolted. Beneath the guide plate, *S*, a similar cutting blade is arranged to suddenly move forward by a cam and cut the thin sheet in two, the piece so cut afterward passing between the second pair of rolls, *V V*, from which it again descends by gravity, and passes between the third pair of rolls, *W W*, and is delivered onto a horizontal table ; or it may be allowed to slide down the inclined end of a cistern of water, and moved slowly forward. By these means it will be possible to cool and stack a ton of plates without any labor or trouble. The thickness of plates capable of being produced will much depend on the size of the rolls ; if drums of 10 ft. or 12 ft. in diameter are employed, it is probable that plates of $\frac{3}{4}$ in. in thickness could be produced, or, perhaps, even thicker. The central space between drums of such large diameter would represent a sort of plate ingot mold with nearly parallel sides for some 8 in. or 10 in. in depth. With reference to speed of production, let us assume the mill to be fitted with a pair of 4-ft. diameter rolls, 18 in. wide, and making four revolutions per minute, and set to produce a sheet having an initial thickness of $\frac{1}{10}$ in., and rolled by the third pair to $\frac{1}{20}$ in.; we should thus have a surface velocity of the first pair of rolls equal to 50 ft. per minute, and making, when finished, 100 plates 18 in. by 12 in., $\frac{1}{20}$ in. thick, and weighing 300 pounds, or equal to a production of one ton of plates in seven and a half minutes. Hence it becomes a question which is the least costly mode of dealing with a ladleful of fluid steel, forming it into massive ingots in molds, or making it into thin sheets in the manner proposed.

It appears from Sir Henry Bessemer's paper, above quoted, that he did nothing to develop the process after his experiments in 1856 for over thirty years, nor until he had learned that success had been reached in America in the same direction. Meanwhile, Mr. Edwin Norton, vice-president of Norton Brothers, Incorporated, of Chicago, manufacturers of tin-plate and tinware (see the presidential address of Robert W. Hunt, before the American Society of Mechanical Engineers in November, 1891), had been experimenting for some years on the process, and in conjunction with Mr. J. G. Hodgson, had obtained various American and foreign patents. (Apparatus for making sheet metal, Nos. 382,319 and 382,321, May 8, 1888; No. 406,945, July 16, 1889. Apparatus for manufacturing railroad rails, No. 406.944, same date. Manufacture of metal bars or rails, No. 406,946, same date.) As sheet rolling mills under these patents are now working commercially at Whitestone, Long Island,

N. Y.; Chicago, Ill.; and San Francisco, Cal., it appears that to Mr. Norton is due the credit of the successful introduction of the process of rolling sheets, bars, etc., from fluid metal, the first experiments on which were made over forty years before by Mr. Bessemer, just as Mr. Bessemer is entitled to the credit of the successful introduction of the Bessemer process, although William Kelly, an American, had experimented with and obtained patents upon it before Bessemer.

We illustrate herewith the process patented by Messrs. Norton and Hodgson for rolling rails and shapes. The underlying principle is to subject the molten metal to pressure between rolls, the conformation of the first rolls being such as to compress the flowing metal into very nearly the shape of the finished form; subsequent rolling is continuous, and in a direction to bring

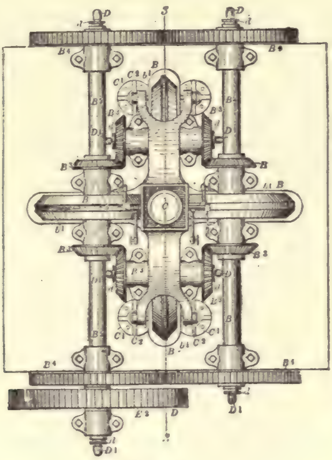


Fig. 11.

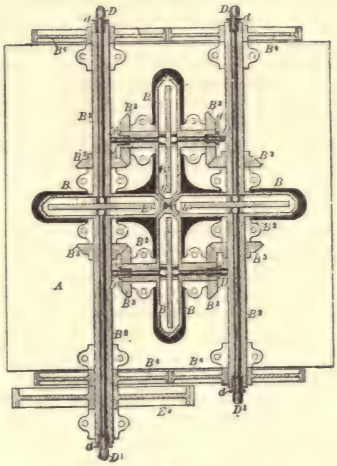


Fig. 12.

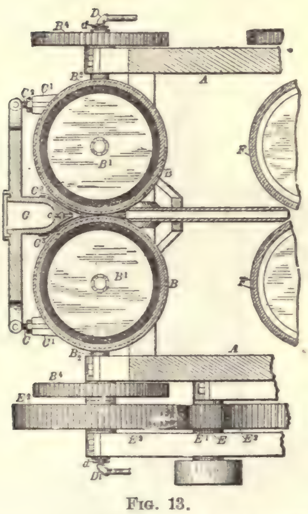


Fig. 13.

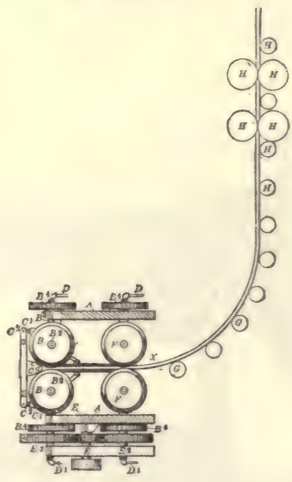


Fig. 14.

Norton's process of rolling fluid metal.

to exact size, and to further compress the metal; also the speed of the rolls is such as to prevent damming of the metal; that is, the speed is such as to provide for a continuous stream of practically a constant cross-section. It will be understood that there is very slight pressure on the initial rolls; these rolls are kept cool by interior water circulation. In the engravings, Fig. 11 is a plan view of the apparatus devised, and Figs. 12, 13, and 14 are, respectively, a central horizontal section through the axes of the rolls, a vertical section on *3*, *3*, of Fig. 11, and a side elevation partly in section. The first rolls—in this instance four in number—are formed at their peripheries so as to present a space between them similar to the section of an ordinary rail. Directly over these rolls the molten metal passes to the rolls through the spout or channel. The following description is taken from the patent specifications: As indicated in Figs. 11, 12, 13, and 14 of the drawings, the working or

meeting faces or peripheries of the rolls, B, are given a shape or configuration to form an ordinary railroad rail. They may, however, be shaped to give the space or passage, b, any desired cross-section, and thus produce a bar of any form required. The rolls, B, have beveled faces, b', which meet or roll against each other, and serve as stops for the several rolls against each other, so that the space or passage, b, for the metal will always be maintained of a uniform size, and thus produce the rail or bar of a uniform cross-section throughout. The rolls, B, are each made hollow, and preferably with a central web, B', and the shafts, B^2, are also made hollow, so that the water or other cooling fluid or liquid may be made to circulate through each of the rolls for the purpose of keeping them cool or of the desired temperature. The hollow shafts, B^2, are each furnished with a packing or stuffing-box, d, at each end, by which they are connected with the inlet and outlet water pipes, D D'. The pouring bowl or vessel, C, is supported by any suitable means above the rolls, B, during the pouring operation, preferably by standards, C', furnished with adjusting screws, C^2. The pouring nozzle, C, is preferably furnished with a valve or device, c, for opening and closing the discharge passage. The hollow shafts, B^2, of the rolls are all geared together, so that they revolve or roll together at the same surface speed. The gearing employed may preferably be bevel gears, such as indicated at B^3. Two of the shafts, B^2, are also geared together by spur gears, B^4. E is the driving shaft, having a gear, E', which meshes with a gear, E^2, on one of the shafts, B^2. The pouring bowl or nozzle, C, is furnished with a guide or shield, C^3, extending down to near the meeting point of the rolls. This is designed to prevent the metal from splattering at the beginning of the pouring operation. A greater or less number of rolls than four may be employed. F represents a second series of rolls, arranged preferably directly below the chilling rolls, B, and between which the bar, x, passes as it issues from the chilling rolls, B. The series of rolls, F, are preferably of the same form and construction as the rolls, B, being hollow and having the same connections for passing water through them, so that they may operate as chilling rolls as well as to further roll, compress, and finish the rail or bar produced. The rolls, F, may, however, be of any ordinary or known construction. The series of rolls, F, is preferably like the series, B, composed of four rolls revolving together. G is a curved guide or conveyer, consisting preferably of a series of rolls or idle pulley wheels, arranged in a curved path to curve and guide the bar as it issues from the rolls, F, to the horizontal conveyer or series of rolls, H. Some of the rolls, H, are preferably driven and operated to further roll and straighten the rail or bar, as well as to convey it along or away. The curved guide, G, also affords some slack in the rail or bar between the chilling rolls and rolls, H H, to compensate for difference in speed or slipping.

Rope Driving : see Belts and Cranes.

ROPE-MAKING MACHINERY. HEMP ROPE.—*Preparation machinery* may be divided into two classes : the drawing or single-chain machine, and the heckling or double-chain

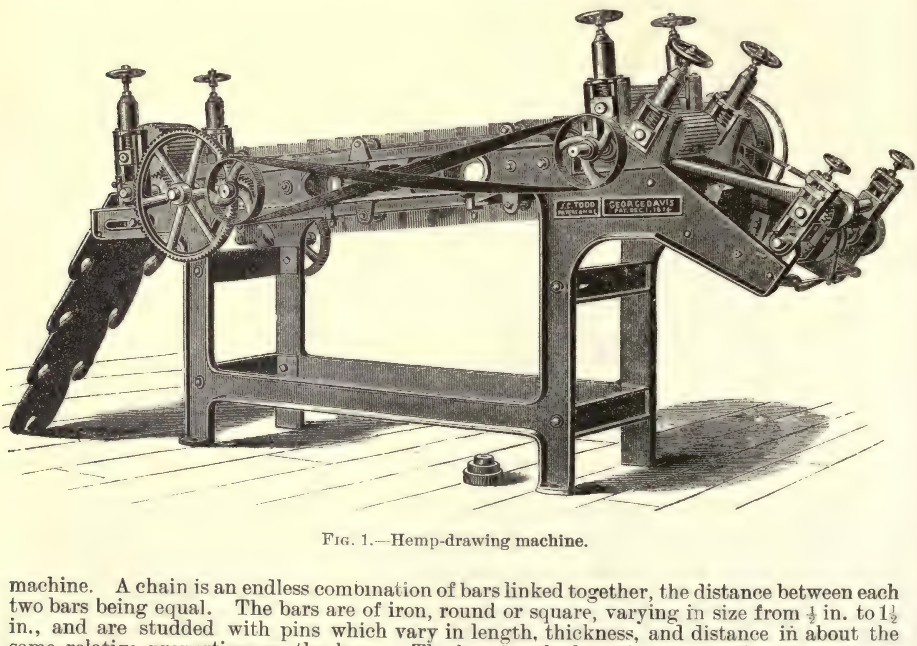


FIG. 1.—Hemp-drawing machine.

machine. A chain is an endless combination of bars linked together, the distance between each two bars being equal. The bars are of iron, round or square, varying in size from $\frac{1}{2}$ in. to $1\frac{1}{2}$ in., and are studded with pins which vary in length, thickness, and distance in about the same relative proportions as the bars. The heavier the bar, the coarser the pin, and *vice versa;* being largest at the beginning of the preparation, and decreasing in size on each successive working machine. At each end of a bar is a "dog," which is moved through guide bars, placed on the sides of the machine, in such a way as to keep the pins in a vertical

position. The chains are moved by means of a carrier-wheel, consisting of from five to ten pinions, the distance between each, or width of the pinions, being equal to the distance between the bars. The carrier-wheel is connected to the motive power by gearing, thus permitting changes to be made in the speed of the chain.

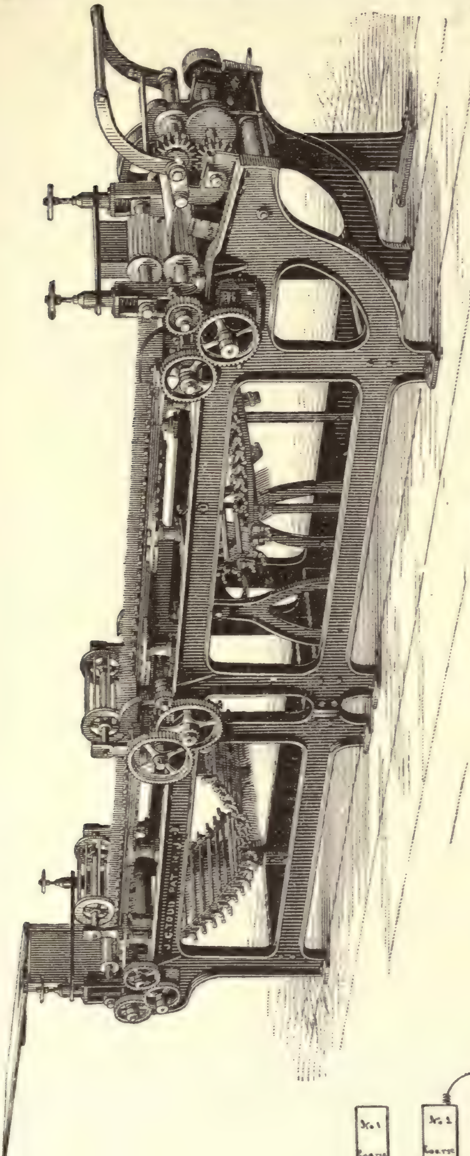


Fig. 2.—Breaker, spreader.

The single-chain machine, Fig. 1, consists of a chain and a pair of fluted iron rollers, placed close to one end of the chain. The rollers, or drawing rolls, as they are called, have a speed of from four to six times that of the chain, and in consequence draw the body of hemp which is on the chain into a sliver four or six times the original length. The term, head of a machine, refers to the end having the drawing rollers.

The second class of preparation machines, Fig. 2, is heavier and stronger than the machines described.

In addition to the chain and drawing rolls of the first class, these machines possess a second chain, moving at from one-sixth to one-tenth the speed of the front or fast chain, the chain nearest the head of the machine. These two chains, one moving six or ten times faster than the other, heckle or comb the hemp, forming it into a sliver made up of the hemp fibers, all extending in the same direction.

We are now ready to understand the preparation of the hemp for the purpose of spinning. The process of preparing and spinning Manila, Sisal, Russian, and American hemp is substantially the same. The hemp is received in tightly compressed bales, which are opened, and each bundle or sheave untied and shaken by hand. It is then passed through a softening machine, consisting of from six to ten pairs of heavy fluted iron rollers. An oil sprinkler at the head of this machine enables the operator to distribute over the hemp a quantity of oil varying according to the kind of hemp, as well as to the use to which the yarn or rope is to be put. The

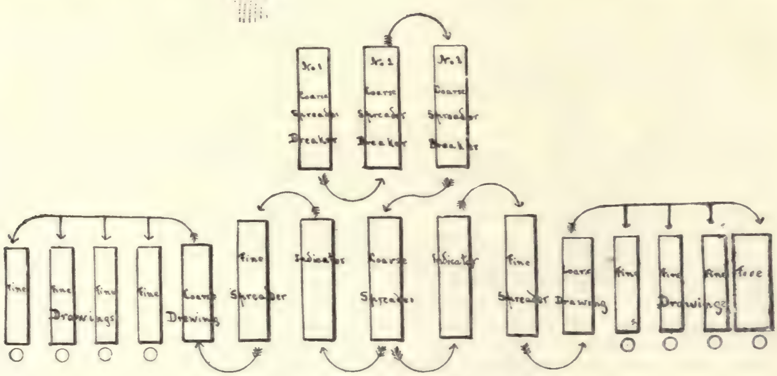


Fig. 3.—Arrangement of a set of hemp machines.

hemp is softened, the fibers separated, and, in the case of Sisal, is ready for the heckling

and combing process. In the case of Manila, owing to the fineness and softness of the hemp at the top or seed end, the fibers are not separated, but are bunched together into a towy mass. In order to separate the fiber and remove the tow, an operation termed scutching is introduced. A bunch of hemp is seized at the middle of its length, and the seed or top end thrown against the rim of a swiftly revolving cylinder. The rim of this cylinder is thickly studded with steel pins or blades about 4 in. long. Being held so that the seed end comes in contact with the rapidly-moving pins, the hemp is teased out, the fibers are straightened, and the tow removed from the hemp, and thrown from the cylinders by centrifugal force. The hemp is sent to the breaker, Fig. 2, a machine of the second class, on the slow chain of which it is fed, and firmly held by the pins which pass through it. In front of the slow chain is the fast chain, the relative speeds being about as 10 to 1. The hemp being firmly embedded on the slow chain, and the pins of the fast chain passing through each portion of the hemp as presented, the fiber is straightened out, and in each revolution of the fast chain a body of hemp is drawn into a sliver of ten times the original length. Naturally, this sliver is not even or uniform throughout its length, due in most cases to irregular feeding, unequal softening of the hemp, and to riding over the pins on the fast chain. To correct the inequalities, 6 or 8 slivers are fed on the slow chain of a second breaker, which operation further completes the separation and straightening of the fiber, and at the same time makes the sliver more uniform throughout its length. The subsequent operations are essentially the same as described above ; 6, 8, or 10 slivers are placed behind spreaders, Fig. 2, consisting of a slow and a fast chain. The bars in these chains are in each successive working brought closer together, and also the pins are finer, and the distance between each two bars or pins made smaller in each case. Sisal receives from 5 to 8, and Manila from 4 to 6 workings on the double-chain machines. The sliver is then considered sufficiently even and the fibers soft and elastic. A number of such slivers are placed back of a drawing frame or single-chain machine, Fig. 1, to be drawn to a size which will admit of its being spun into yarn or thread of from 300 to 600 ft. to 1 lb. The drawing frame, Fig. 1, is made up of a chain studded with fine pins, and in place of a fast chain is a pair of fluted iron rollers, with a speed of four or five times that of the chain. This difference in speed will reduce the slivers to one-fourth or one-fifth the original size by drawing them to a single sliver four or five times the original length. After one or two workings on the drawing frames, the sliver is ready for the spinning or jenny room, where it is spun or twisted into yarn of any desired size.

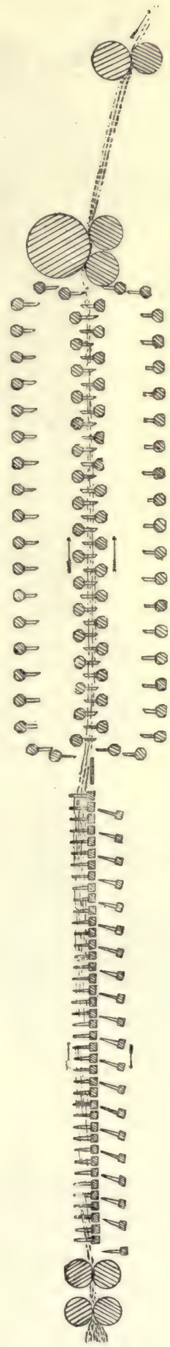


Fig. 4.—Combe, Barbour & Combe's chain.

The diagram, Fig. 3, shows the usual arrangement of the various machines making up a "set." The capacity of this set is from 12,000 to 15,000 lbs. per day.

The main defects of this system are the tendency of the fiber to ride over the pins of the fast chain (which is natural, on account of the speed of this chain), and in the space between the last pin in the detaining chain and the first on the fast, or combing chain, which is of necessity so great as to let a portion of the stock go from one to the other without being cleaned, combed, and straightened. These defects cause an amount of raw or unworked hemp to show in the sliver, and render the number of successive operations necessary to repair this fault.

The machinery, as described and illustrated above, is the type in general use throughout the United States.

Fig. 4 shows the style of chain used in foreign preparation machinery. The great difference between these machines and those previously described is in the mode of drawing the bars or gills. As we have seen, in the former machines the bars are driven by a carrier-wheel, but the bars in this machine are driven by a horizontal screw, which forces the pins in and out of the fiber at right angles. The front chain in this machine consists of two sets of bars, one above the other, shown by Fig. 4, producing an absolute certainty of action, as the pins in the bars intersect and prevent any possibility of the fibers riding over the points of the pins. And on account of the intersecting bars there are twice the number of pins in action at the same time as would be in the case of the machine shown in Fig. 3. The action of this machine is, therefore, much better than that of the former set. There still remains the fault due to the distance between the chains.

The latest form of preparation machine invented by A. W. Montgomery, New York, is

shown in Fig. 5. It embraces the advantages of the old lapper system, and of the Good or two-chain system. This machine consists of the detaining roller, with withdrawing pins of

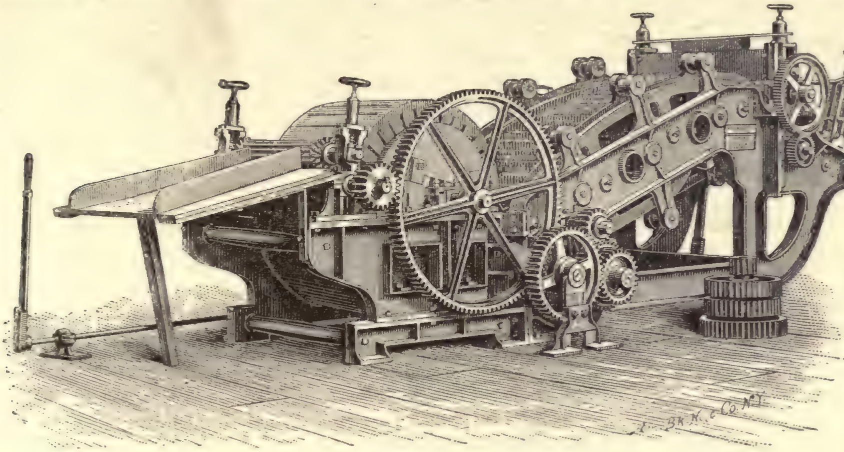


FIG. 5.—Montgomery breaker.

the former, close in front of which is the fast chain of the latter system. In this machine the distance between the detaining pin and combing pin is only 6 or 7 in. Hence only a small portion of the fiber escapes the heckling action in the first working through the machine, and is pretty sure to be thoroughly cleaned and straightened the second time through. The chain takes the hemp from the cylinder, on a line tangent to the detaining cylinder, thus forcing the hemp firmly between the pins and on the bars. The draw at this point is nearly constant. Immediately in front of the chain are the drawing rollers, which, drawing the hemp in about the proportion of one to one and one-half, forms it into a compact sliver. Five workings on this system accomplish the work done by the system represented above. Four workings on machines similar to Fig. 5, and one drawing, fits the sliver for the spinning-room. The capacity of this system is from 18,000 to 25,000 lbs. per day. The arrangement of a "set" is shown by Fig. 6. The jenny, illustrated by Fig. 7, consists of a slow-moving

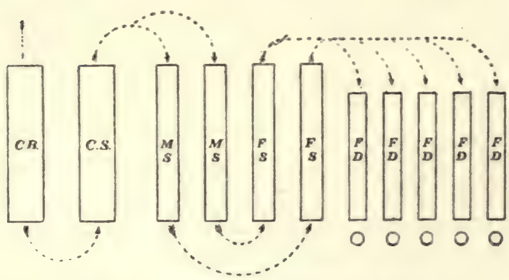


FIG. 6.—Arrangement, Montgomery system.

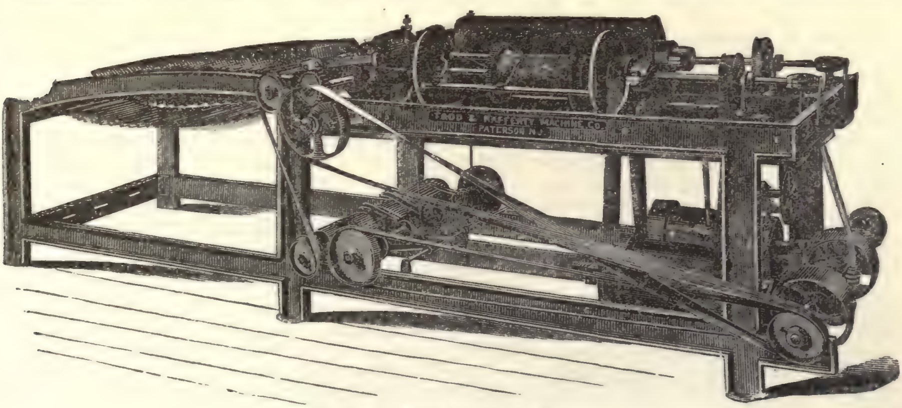


FIG. 7.—Hemp spinning-jenny.

chain, in front of which is the flier containing a pair of capstan wheels. Each revolution of the flier causes the capstan wheels to draw in a certain uniform amount of sliver. Each

revolution of the flier puts one turn into the hemp drawn through, forming it into a thread; and at the same time winds an equal amount of spun yarn on the bobbin, which holds about 15 lbs. The bobbins are sent to the rope-walk or rope-machine room to be made into rope. Rope of a diameter of $\frac{3}{4}$ in. or less is made on rope machines, Figs. 8 and 9. That of larger diameter is made in the rope-walk, although rope machines have been built to make the larger sizes. Fig. 8 represents the "former," on which the yarns are twisted into strands, and Fig. 9 the layer, on which these strands are "laid up" into rope. The size of a rope determines the number of threads necessary to make it. One-third this number are twisted together into a strand when a hawser-laid rope is wanted, and one-fourth when a shroud-laid rope is required. Either the three or four strands, as the case may be, are in turn twisted together to form a rope. The two operations are performed at the same time on some rope machines, but separately on others and in the rope-walk. A description of the rope-walk process will suffice for both. In the rope-walk the bobbins are mounted upon a rack; the requisite number of threads to make a strand are passed through the same number of holes in a perforated plate to and through a trumpet-shaped tube, and fastened to a hook on the forming machine. This hook can be geared to revolve a definite number of times per each foot of travel of the "former;" in this way a regular amount of turn is put into the strand. The turn varies with the size of the strand, more turn being required in the small than in the large sizes. The length of the track limits the travel of the "former" and the length of the strand. Six strands are usually made at one time. As many strands as are required for the rope are stretched at full length along the walk, and attached at each end to hooks on the laying machines—the foreboard, being at one end, is stationary, and the

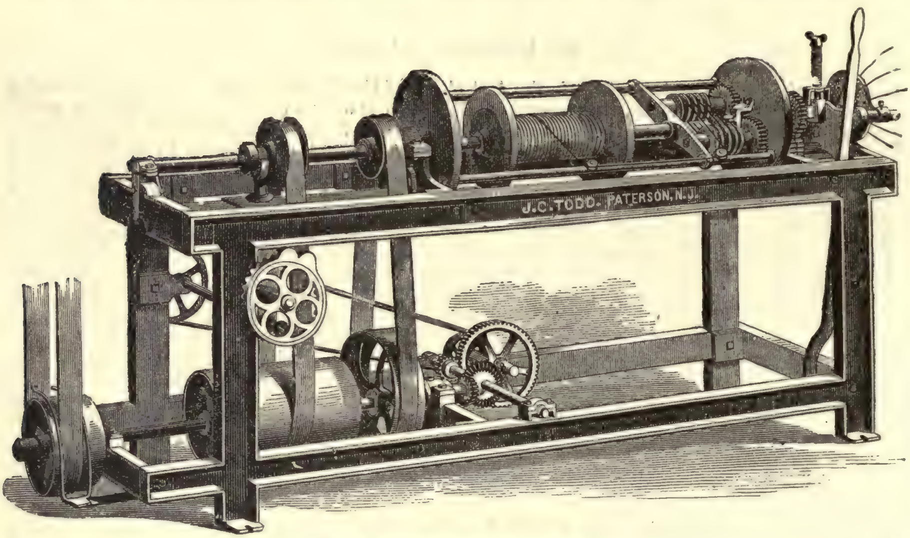


Fig. 8.—Strand-forming machine.

traveller at the other moves up and down the walk. The hooks of both machines are set revolving, continuing the "foreturn" placed in the strand during the forming process. Why this step is necessary has been explained. At one of the "laying" machines, each strand is in turn removed from its hook and laid in one of three equidistant concentric grooves of a cone-shaped block called a "top," and then fastened together on the center hook of the machine. The hooks of the two machines are now set revolving, the direction of turn at one end being the opposite of that at the other end. As a consequence, being fastened at one end to one hook, and at the other end to three hooks, the strands turn or twist on themselves at the end where there is one hook. As the twist is communicated to the strands between the single hook and the "top," the latter is pushed forward, leaving the laid rope behind it. Care must be exercised in guiding the block, for on its uniform motion depends the firmness of the rope, as well as the regular and uniform character of its "lay."

Trautwine says: "The tarring of ropes is said to lessen their strength, and when exposed to the weather, their durability also. We believe that the use of it in standing rigging is partly to diminish contraction and expansion by alternate wet and dry weather." Haswell speaks of tarred ropes being 25 per cent. weaker than white or untarred ropes. Russian hemp rope agrees with the conclusion laid down by both writers; but the Manila and Sisal hemp ropes were not affected at all in strength, although 20 per cent. of tar was added. The loss in strength was due to the tarring process. The ropes were formerly passed through a tar bath of a temperature of from 210° to 240° F. This temperature, being sufficient to singe off the hairs or stray fiber usually appearing on the surface of a rope,

was high enough to cause it to crisp, and hence by impairing the elasticity and stretch of the rope, cause it to break at from 20 to 35 per cent. less weight than before it was tarred. By the use of the Montgomery tarring process, the necessity for the high temperature of the tar bath is avoided, and the rope is treated to a bath at 140° to 150° F. Rope so treated is uniformly tarred, and at least maintains, if it does not improve, its strength. This process liquefies but does not evaporate the tar, as happens when the tar is heated to and maintained at a high temperature. The light oils, and even the carbolic oils, of tar will be driven off at the temperature of 250°, and in a short time there would be nothing left but hard pitch. Rope tarred with such a substance will immediately upon its removal from the bath become hard and stiff, while for actual use tarred rope should be soft and pliable. In the latter case the life of the tarred rope is equal to, if not greater than, of a

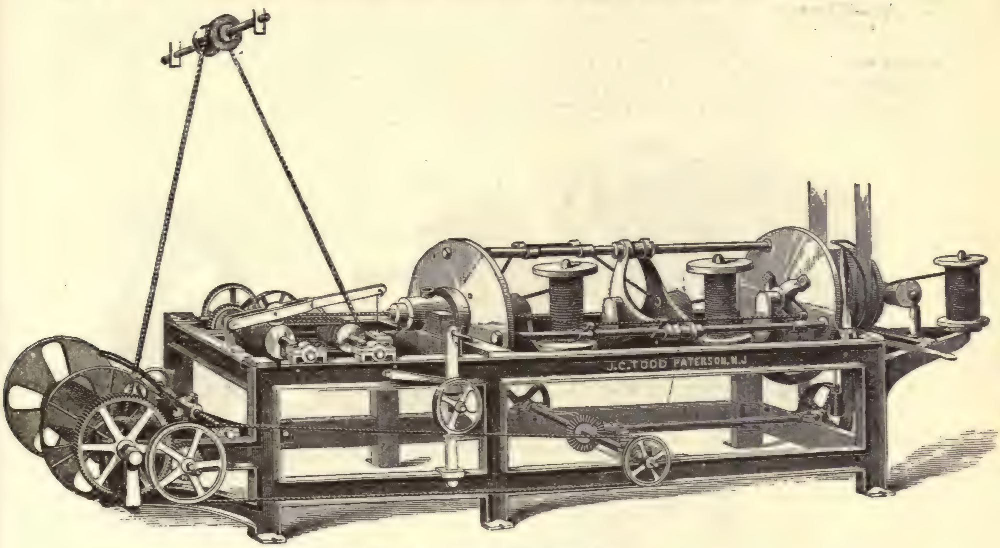


FIG. 9.—Rope-laying machine.

white rope of the same size ; and at the same time the amount of expansion and contraction is reduced to a minimum. Russian and American hemp, being soft and spongy in their nature, absorb the tar, swelling the fiber, and consequently lessening its stretch. With the hard and wiry fiber of Manila and Sisal, on the other hand, the tar remains upon the outside, acting as a preservative against the weather. A peculiarity about tarred ropes is that the three strands are liable to break at one time. In the case of white rope, one strand breaks while the remaining two set themselves, and will stand nearly seven-ninths, instead of two thirds, the strain which caused the first strand to part. In practice the greatest number of breaks occur at the splices, caused probably by the sawing of a strand on its neighbor. The more turn or harder laid the rope, the stronger it is. This, however, is true only up to a certain limit, as excessive turn would of itself cut the rope. "Hard" turn ropes were found to be fully 10 per cent. stronger than ordinary turn ropes.

Recent tests made at the Watertown Arsenal, to determine the breaking strain of Manila rope, gave as the strength per square inch of section 9,500 lbs., when the rope was clear of splices, and 7,000 lbs. when spliced.

WIRE-ROPE MACHINES.—*Lang's Laid Rope.*—In the construction of roping known as "the Lang lay," the wires forming the strands, and the strands comprising the rope, are all laid in the same direction. Upon comparing the two illustrations, Figs. 10 and 11, the difference between an ordinary rope and one according to the last-mentioned construction will be readily apparent. In Fig. 11, it will be noticed that both the wires composing the strands and the strands forming the rope are laid in a right-hand direction, and, consequently, the component wires follow a dextral spiral axially to the rope. An advantage of this construction is that a longer continuous surface of any wire is exposed to wear, and the crowns of the strands are less pronounced; therefore, whilst more uniform wear is promoted, the cutting tendency of the wires is reduced, and the durability of the rope correspondingly increased.

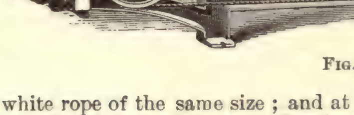


FIG. 10.—Ordinary rope.

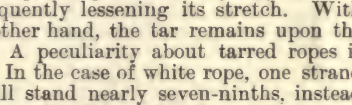


FIG. 11.—Lang's rope.

Latch and Bachelor's Locked-coil Rope.—The principle incorporated in this manufacture

consists in the employment of various suitably shaped wires, which, when closed together, interlock and present a structure with a uniform wearing surface, in which each component wire is permanently held in its proper normal position. The transverse section, Fig. 12, shows a rope composed of an ordinary wire core, around which a series of cylindrical and radial wires are closed, followed by an outside shell of sectional wires, which are locked or held down in position. The various succeeding layers of wires are laid in alternate directions—*i.e.*, one to the right hand and the next to the left, and so on, as in the manufacture of some compound strands previously referred to.

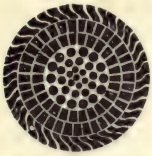


FIG. 12.—Wire rope section.

The modern type of wire-stranding and rope-closing machinery is shown in Figs. 13 and 14. The selected wires of requisite gauge are contained or coiled upon the bobbins shown, or mounted in the "flyers," carried by the circular frame, which is fixed to a horizontal shaft mounted in bearings, so as to be free to revolve through the intervention of appropriate gearing. The outer ends of the wires are passed through apertures provided in the annular framing and nozzle plate running in the headstock bearing, and thence are carried through the fixed closing block or die—shown closed by means of the weighted lever—to the

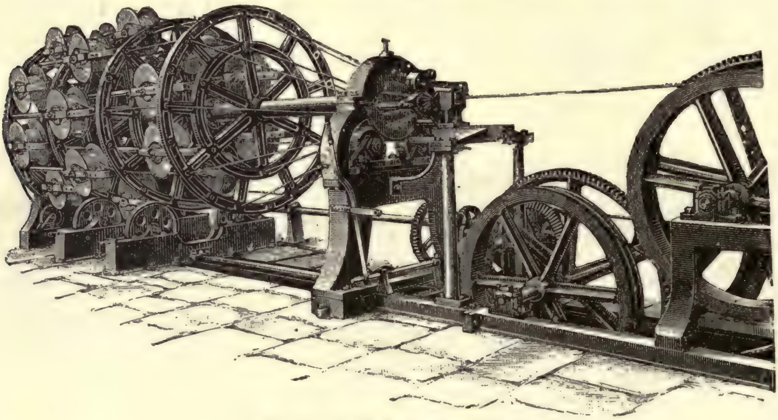


FIG. 13.—Wire-stranding machine.

draw-off drums. The hempen or wire core is drawn in centrally from the back of the machine through the tubular horizontal shaft, and as the machine revolves and draws in the core, the wires are twisted spirally round the same. The tandem grouping or arrangement of the bob-

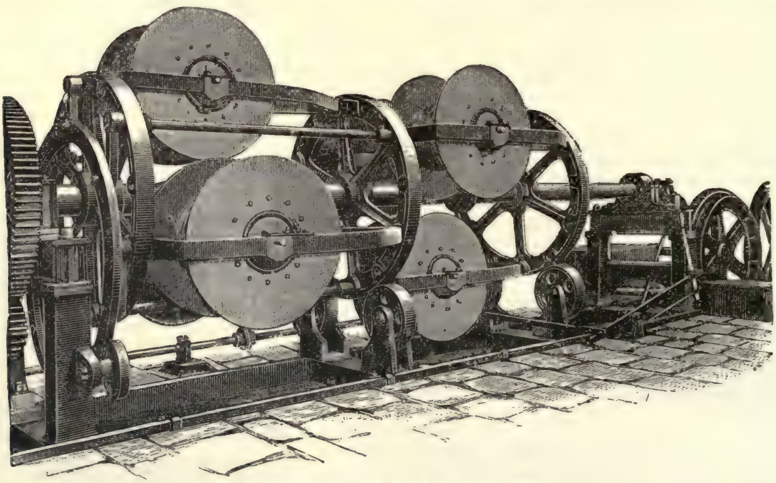


FIG. 14.—Wire-rope closing machine.

bins is worthy of notice, and consequent easy angle at which the wires are concentrated at the nozzle plate, and drawn through the closing die. In this manner the strands are twisted up without bending or straining the component wires, whilst any undue slack arising from any

unequal running of the bobbins is ingeniously pushed back from the aforesaid die. The bobbins mounted in the flyers, or fork-shaped frames, are controlled by an eccentric motion at the back of the machine. as shown in the closing machine, Fig. 14, so that whilst the circular carrying frame revolves, they are always maintained in a vertical attitude, in order to prevent any individual twisting of the wires. Each bobbin is mounted on an independent transverse axis, and provided with a tension band and adjusting screw, so that they may be set to pay the wire out uniformly. The draw-off drum at the opposite end of the machine is driven by a train of gearing actuated by a spur-wheel fixed on the revolving portion of the machine, and proportioned to drive the said drum at a determined peripheral speed, in order to obtain a required length of lay in the strand. In other words, as the revolving portion of the machine makes one complete revolution, the draw-off drum receives an angular movement, dependent upon the proportion of lay desired, the variation of lays being obtained by the employment of "change wheels." The finished strands are wound upon reels or bobbins, and are afterward placed in the flyers of the closing or rope-making machines, such as represented at Fig. 14, before referred to. This only differs from the stranding machine explained inasmuch that the bobbins are usually confined to six in number, and that they are loaded with strands in lieu of wires. Closing machines are, however, run at lower speeds —*e.g.*, from 30 to 50 revolutions per minute—whilst those for stranding are run up to from 75 to 150 revolutions, and some even up to 300 revolutions per minute.

Roughing Frame : see Cotton-spinning Machines.

Routing Machine : see Boring Machines and Carving Machines.

Rounding and Straightening Machines : see Iron-working Machinery.

ROUTING MACHINES. A routing machine may be used for carving or for working away the spaces between raised portions of relief-engraving blocks, or for gaining. A species of gaining is string-routing, or letting in the risers and treads of steps.

The string-routing machine shown in Fig. 1 is made by P. Pryibil of New York City. There are two swinging arms swiveled to each other, and to a bracket fastened to a post on the wall. The end of the second or outer joint of the arm carries a dove-tail cutter, and can be moved freely in any direction by two handles fastened to the two arms. The arms are hollow to give lightness and stiffness, and the swivel bearings are very long. There is a vertical adjustment to regulate the depth of cut, and an adjustable step. The machine is used with forms made of three thicknesses of hard wood glued together, with the grain crossing. To use them and the machine the string piece is marked out in the usual manner, and laid on the table of the machine ; the form is placed thereon and fastened to it by two clamping screws. The cutter is then fed in, guided by the form, and cuts out the material to form the riser, tread, nose, and wedges. The same form produces both right and left-hand runs.

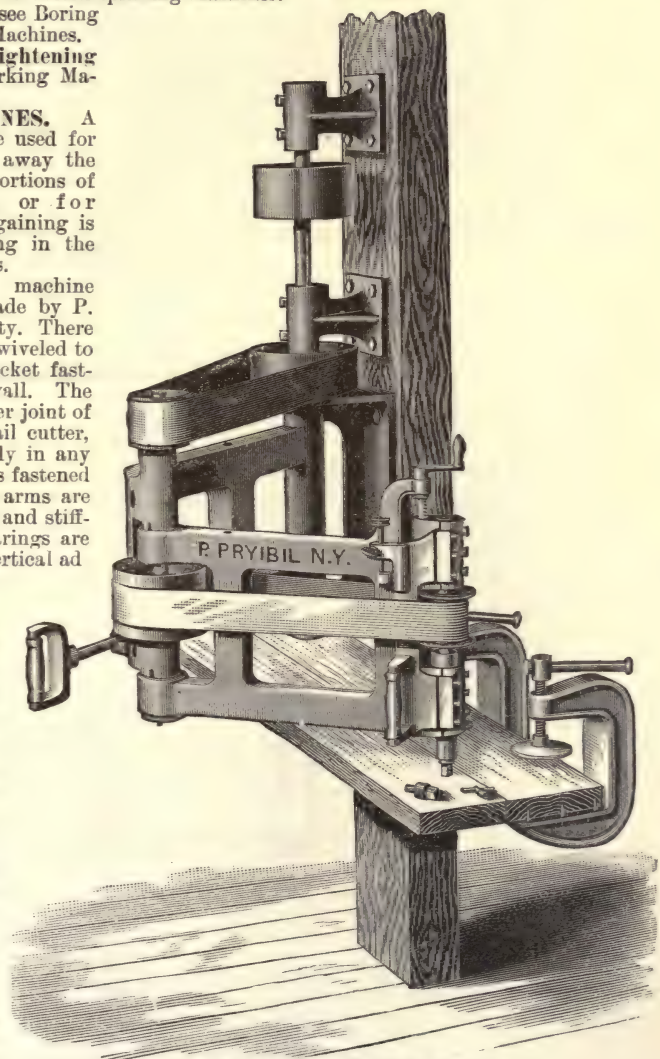


Fig. 1.—The Pryibil string-routing machine.

Roving Frame : see Cotton-spinning Machinery.

SAFES AND VAULTS. I. Burglar-proof Construction.—The highest skill of the safe-maker is now devoted to the construction of strong-rooms and vaults for banks and safe-deposit companies.

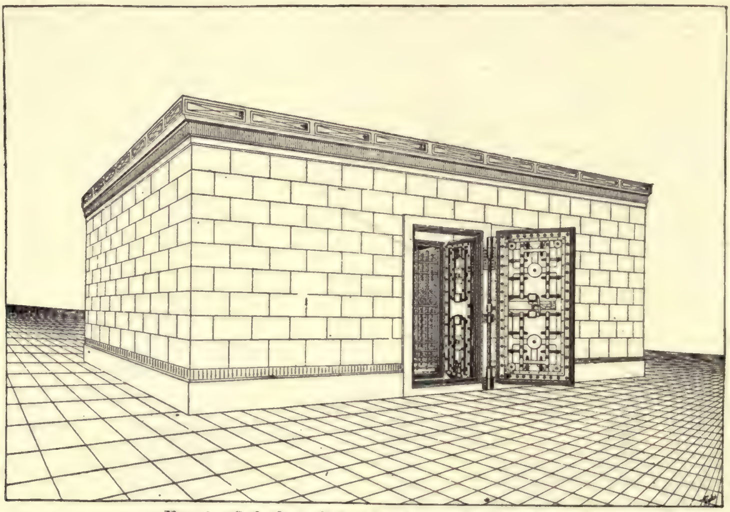


Fig. 1.—Safe-deposit and bank vault. Elevation.

Safe-deposit and Bank Vaults.—Fig. 1 represents a front elevation of a structure intended to be proof against not only fire and burglars, but the depredations of a riotous mob.

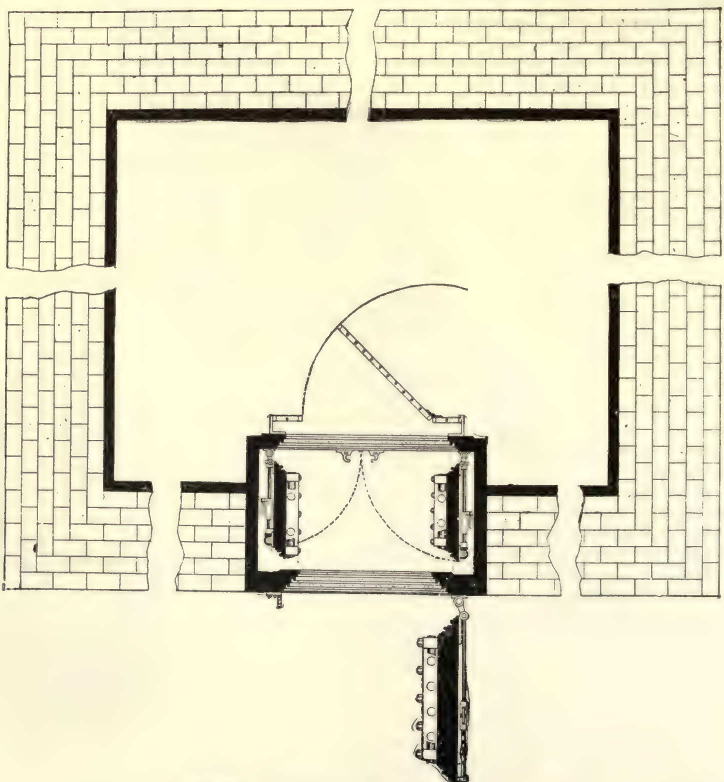


Fig. 2.—Safe-deposit and bank vault. Plan.

A steel vault is provided with an outside wall of stone or brick, 2 ft. in thickness and laid up in cement; the vault rests upon a foundation especially prepared for it, and is usually

erected within and apart from the walls of the edifice in which it is located, so that it may be patrolled on all its sides by watchmen, or by an armed force, should necessity require. When the space within a building to be occupied by the vault is contracted, a fire-proof composition, 6 in. thick, sustained within an iron shell or cladding, is sometimes substituted for the thicker wall of stone or brick.

The architectural design of these structures may be severely plain, as shown in the engraving, or may be embellished with brick and terra cotta, or by cast-iron base moldings and pediment when the outside wall or cladding is of iron.

Fig. 2 represents, however, the plan of a medium cost vault, and shows the steel walls surrounded by brick-work, together with the entrance, which consists of a steel vestibule with inner folding-doors and a single outer door. Many safe-deposit vaults are built with *two* openings or entrances instead of one. The number of patrons to be accommodated renders it desirable to use one set of doors as an entrance, and the second set of doors as a means of departure from the vault.

There is, however, another and far more important reason for the use of two openings. Untold expense and annoyance would be entailed upon the patrons and officials of a safe-deposit or bank vault should the locking mechanism of the doors become disarranged over night, and thereby prevent access to the vault at the regular hour for opening up for business

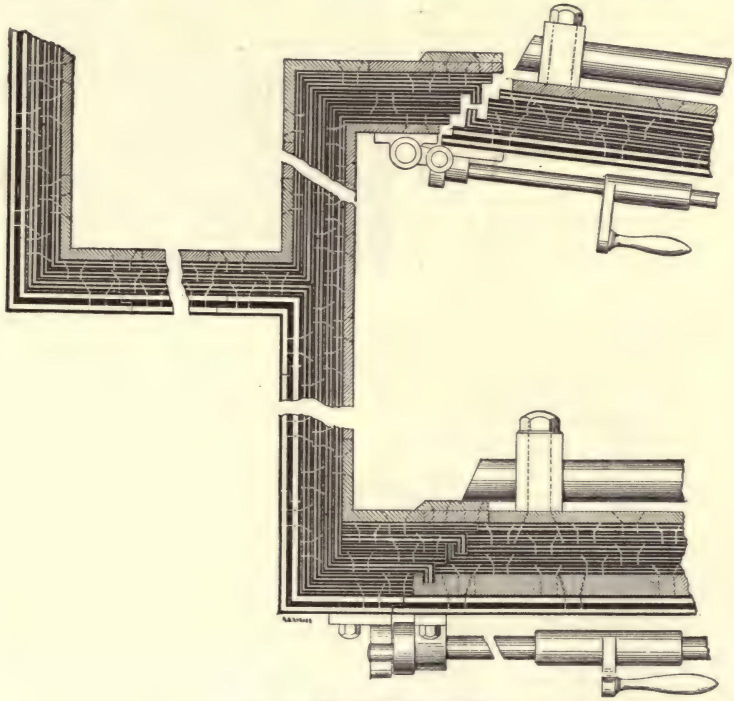


FIG. 3.—Marvin vault. Section.

in the morning, as might happen, despite all reasonable care, if but one entrance is provided. That the locks on both sets of entrances, where two openings are provided, should cause trouble at the same moment is a contingency so remote as to be removed from the necessity for consideration. The vaults of the Marvin Safe Co. are constructed in the following manner:

A corner section of the walls of the vault is shown in Fig. 3, together with the junction of the walls with the vestibule; the jamb and a part of the left-hand folding inner door; and the jamb and a part of the outer or main door. The outer frame of the vault is made of $6 \times 6 \times 1$ in. angles of welded chrome steel and iron, bent and welded at the corners to form tripod sections. The panels formed by this frame are filled in with plates of the same material and thickness. All edges of the angles and plates are rabbeted one-half their thickness, and with $\frac{1}{2}$ in. lap, and engage with similar rabbets wherever plates and angles abut each other. The second layer is formed of plates of welded chrome steel and iron $\frac{1}{2}$ in. in thickness. All the corners of the second layer are formed of angles wrought from the plates. The plates of the second layer are placed at right angles to those of the outer layer, and are secured to the latter with welded steel and iron counter-sunk bolts $\frac{3}{4}$ in. in diameter and spaced not more than 10 in. from centers. These bolts pass through the second layer into but not through the outer layer, the purpose being to "blind" all fastenings on the surface. The third and fourth layers are also of $\frac{1}{2}$-in. welded chrome steel and iron, turned at the

corners to form angles. The third layer is placed at right angles to the second layer, and secured thereto with the $\frac{3}{4}$-in. welded steel and iron bolts, which pass through the third layer, and are tapped into the full thickness of the second layer. The fourth layer parallels the second layer, and is bolted to the third layer by the $\frac{3}{4}$-in. welded steel and iron bolts passing through the fourth layer. The fifth or final layer is of Bessemer steel plates, $\frac{1}{2}$ in. in thickness, secured to the fourth layer by similar bolts to those used in the preceding layers. The total thickness is 3 in., but the thickness is varied by the addition to, or reduced by taking from, the number of plates or layers in the vault, according to the degree of security desired. The vestibule is constructed of the same material and in the same manner as the body of the vault, except that in most cases its thickness is increased $\frac{1}{2}$ in. over that of the vault itself The vestibule is usually telescoped into the vault, as shown, and is joined to the walls of the vault with reversed angles, as shown. The outer or main door is usually made 5 in. thick, of alternate layers of the five-ply welded chrome steel and iron, as shown, secured together with the $\frac{3}{4}$-in. welded steel and iron bolts, placed at average distances of 8 in. from centers, and great care being observed, as in bolting the layers of the vault, that no two bolts align each other. The bolt frame is of steel, forged into a continuous frame, and secured to the inner edge of the door by conical bolts, made of the best wrought iron, with the conical parts of hardened welded chrome steel and iron. These bolts start with and extend through the sixth, seventh, and eighth layers into and through the bolt frame. The inner doors are made folding, as shown in Fig. 2, and the right-hand door overlaps and interlocks with the left-hand. These doors are usually made $3\frac{1}{2}$ to 4 in. in thickness of materials, and put together in the same manner as already described for the outer door. Through the bolt frame of the outer door extend not less than twenty-four round revolving steel bolts, each 2 in. in diameter. They are checked by the time-lock and by two four-wheel combination locks, so arranged as to require that both locks must be unlocked before the bolts can be retracted. They are further arranged so that, if desired, one of the locks will release the bolt-work. Each inner door is fitted with not less than sixteen round revolving bolts, $1\frac{3}{4}$ in. in diameter, also checked by two four-wheel combination locks, so arranged that one lock, at least, on each door must be unlocked before the bolt-work of either door can be retracted. The lock and bolt-work spindles are of steel, in conical sections, closely ground to fit, and packed so as to be absolutely proof against the introduction of explosives. They can be neither driven in or drawn out, and by reason of their peculiar construction do not develop the structural weakness which appears in former methods of spindle construction. In addition to the locks on both the outer and inner doors, each door is equipped with a gravity device, to operate the instant the locks are forced from the inner surface of the doors, so that the doors will remain locked or fastened, even though the locks themselves should by any means be driven from their fastenings. All the doors

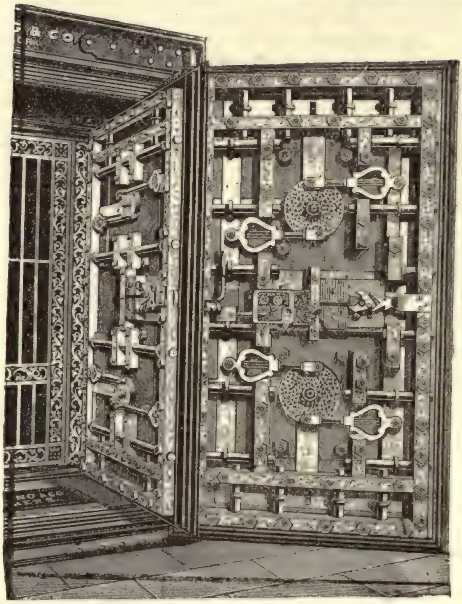


Fig. 4.—Entrance to Herring vault.

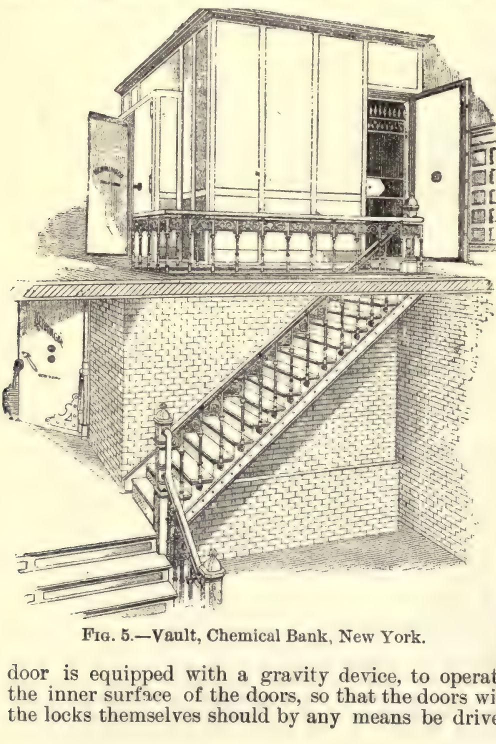


Fig. 5.—Vault, Chemical Bank, New York.

are hung to compound hinges with a vertical part and two cross-arms. They operate in an anti-friction or ball-bearing cup, and are so arranged that the sag of the door may be easily taken up. The finish of the locks, bolt frames, and bolt-work is very elaborate, and is protected from rust and dust by being enclosed behind plate-glass doors, hung to the inside of the bolt frames. The day gate is usually hung back of the vestibule doors, and is made of polished steel vertical bars, with flat polished frames and cross-bars, tipped with polished brass ornaments. It is hung to gravity hinges, and is fitted with a key-lock and lock-guard plate.

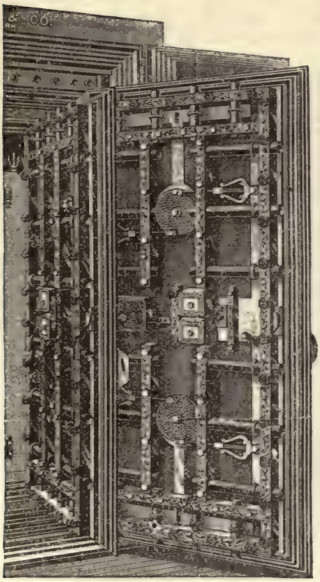


Fig. 6.—Vault, Chemical Bank.

Within a very recent period the doors of several vaults and safes have been built by this company with what is termed "automatic bolt-work" or "bolt-actuating devices." The "automatic device" aims at a *solid* door without any lock or bolt-work spindles piercing it. The operation of locking is accomplished automatically, in closing the door, by means of the tripping lever, located on the outer edge of the bolt frame, which impinges against the jamb of the vault or safe when the door is closed releasing the locking springs, which thereupon shoot the bolts behind the jamb and lock the door. The door will then remain locked for the number of hours for which the time-lock is set. When the proper time arrives the hand of the time-lock will remove the hook which connects with the compound levers, and the unlocking springs will thereupon be released and the bolts retracted. All "automatic bolt-work" and their kindred devices are, as yet, in the experimental stage, and it is not claimed that they have been fully perfected.

Among the more notable bank and safe-deposit vaults are those built in the manner above described by the Marvin Safe Co. for Messrs. Drexel, Morgan & Co., and the Garfield Safe-Deposit Co., cf New York City. Other important vaults are those constructed by Messrs. Herring & Co., of New York, for the Lincoln Safe-Deposit Co., and the Chemical National Bank. The entrance to the great vault of the Lincoln Safe-Deposit Co. is represented in Fig. 4. This is constructed of iron, steel and iron welded, homogeneous plates of hard and soft steel and Franklinite. The vault is entered through the largest and strongest safe doors ever made. There are four sets of double doors, having a combined weight of 48 tons, and yet they are easily opened and closed by means of patent-lever hinges. Massive and highly polished bolts secure the doors on both sides, top and bottom. These bolts are checked by Dexter double bank locks and improved time-locks. Ornate doors of open wrought-iron work are provided for use during business hours. The vault of the Chemical National Bank of New York City is illustrated in Figs. 5 and 6. The vault occupies two floors, and weighs, exclusive of the masonry, almost 260,000 lbs. Both upper and lower vaults are provided with two inner or burglar-proof doors. These are 8 in. in thickness, and each door weighs a little less than 22,000 lbs. Inside of these doors in turn are iron gates for use during business hours. The massive doors just referred to have tongues and grooves which interlock with corresponding tongues and grooves in

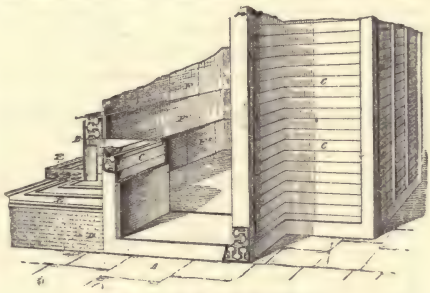


Fig. 7.—Railroad iron vault.

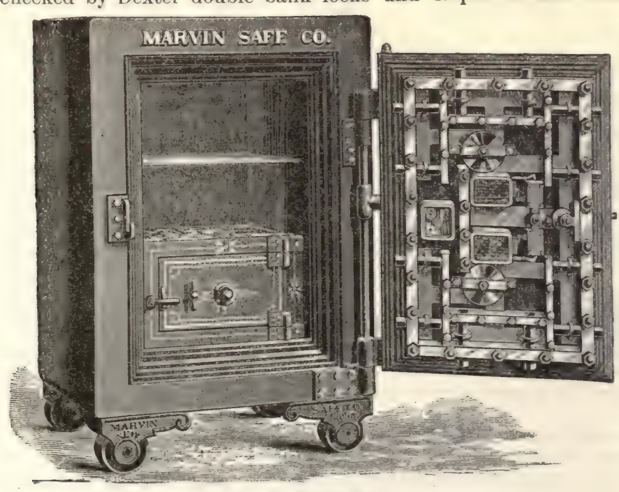


Fig. 8.—Marvin safe.

each jamb, so that when closed the doors are firmly keyed to the body of the structure. There are 20 steel bolts in each door, which secure it on all sides. These doors are made fast by two Dexter bank locks, which may be unlocked by either of two dials. They are safe against a lockout, or they may be arranged to require the presence of two persons, each one controlling a dial with a distinct combination. Besides this, each one of the outer strong doors has a time lock attached. This, however, is not the only protection against burglars. Inside the vaults are 12 Herring's safes, in which the many securities and different funds of the bank are kept separate, fixing individual responsibility to the last degree. Referring again to the upper vault, the fire-proof casing extends back of it to the wall, providing a space in which the books of the bank are stored for safety against fire. Referring to the cut, the door shown at the right in the upper vault leads to the book receptacle just described. It would seem that the precautions taken against loss by robbery or by fire in this bank are as great as may be. In the first place, there is the fire-proof building already described; next the fire-proof casing of the vault, inside of which is the vault proper, and then, in turn, inside of this are safes of the most thorough construction. In view of the fact that the bank has resources amounting to some $30,000,000, the need of these precautions will be appreciated.

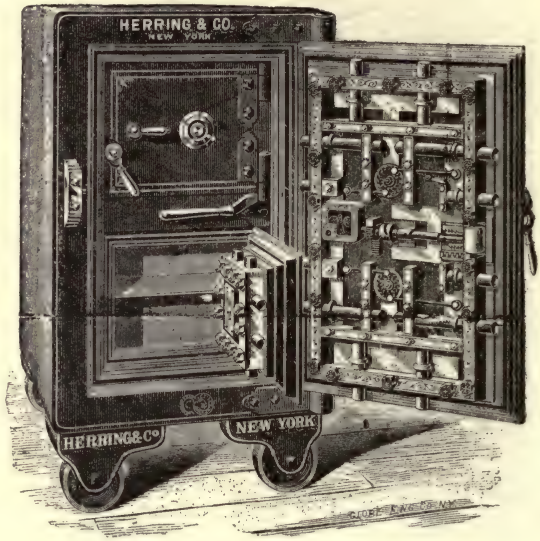


Fig. 9.—Herring safe.

Type of vault, constructed of plate steel and railroad rails, is represented in Fig. 7.

Burglar-proof safes are constructed in the same manner and in the same materials as vaults, being in fact little more than miniature reproductions of the latter. Fig. 8 represents a new form of Marvin safe, made of steel and provided with an inner chest. Fig. 9 is a solid-door bankers' safe, made by Messrs. Herring & Co., which has the novel feature of a solid outer door, with a smooth steel surface, unpenetrated by spindle or arbor. When the time-lock has unlocked at the time set, the bolts may be operated by a mechanical attachment on the inside of the safe door. A locking bar is moved so that the door has a slight play. It is then given an in-and-out movement by means of a cam leverage on the outside of the door. This works the attachment and unlocks the strong bolts. It is arbitrary in its action, not depending upon springs or weights.

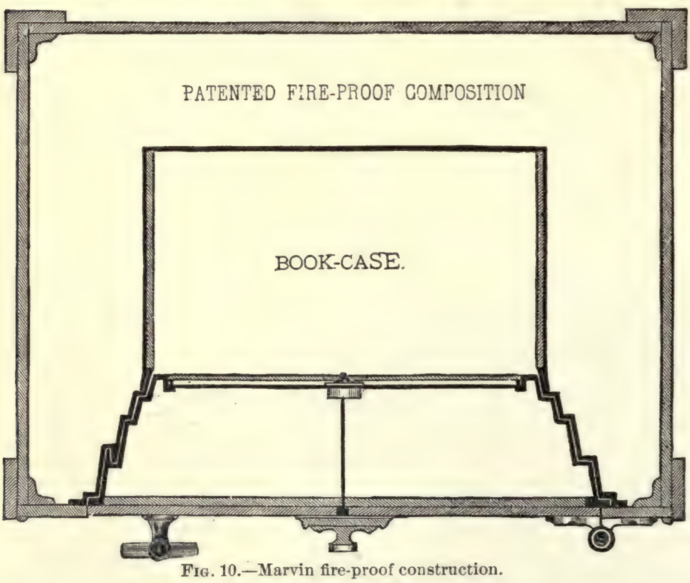


Fig. 10.—Marvin fire-proof construction.

Among the late improvements in safe manufacture, applied by Messrs. Herring & Co., are a new form of hinge, by which the tongued and grooved door is withdrawn perfectly square and true from the jambs in the body of the safe until it is free from the groove with which it interlocks. Safe bodies are made of solid hard and soft steel, or steel and iron welded plates

and angles. The front and back frames are made solid, with welded corners, and the body between these frames is a solid hoop. The back plate is one piece, which is rabbeted into the frame. Bank safes and vault doors are constructed with outside plates 1 in. thick. A step is planed on the edge of the doors, and the plates where they join are also rabbeted. The lock and bolt spindles, as now made by Herring & Co., are provided with a gasket which renders them air-tight. The spindle is a ground fit, and is constructed of the same metal as the safe door. In every case the spindles terminate on the inside, against the solid bolt frame, and operate the locks by geared wheels, which offset. A new bolt attachment holds fast the bolts in the event of the lock being detached by concussion, or any other means, so even if the lock and the spindles are destroyed the bolts will be held secure.

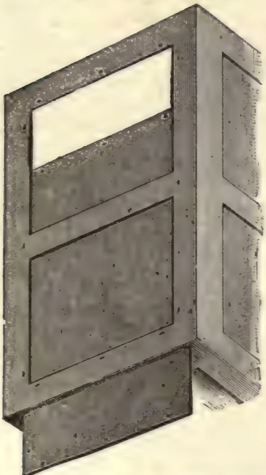


Fig. 11.—Fire-proof construction.

II. Fire-proof Construction.—In Figs. 10 and 11 is shown the construction of the latest form of Marvin fire-proof safe. Both the stepped front frame, in which the door sets, and the frame of the door itself, are shown by the heavy black lines, Fig. 10, separated by a fine white line, which marks the joint or opening between the door and the front frame. This stepped front frame is constructed to form a tongue and groove with one of its steps—here shown as the second one—which extends along or around the door opening, side and top and bottom of said stepped front frame, but not down the side against which the back or hinged side of door sets. The door itself is made with a corresponding tongue and groove on like sides, so that the tongue of the frame and the door interlock by the fit of the tongue of each one in the groove of the other, said tongues breaking joint with the frame and its door. The door is constructed on its hinge side with a heel tongue or projecting flange which extends along its entire side, from top to bottom, without a break. When the door is closed, this flange is projected into a groove of corresponding size, within the first step of the front frame, thus closing and breaking the joint, crack, or opening between the door and stepped front frame at the hinged side. A recess in the inner face of the door receives a sheathing of material which is a non-conductor of heat, and forms an air chamber which prevents communication of heat from the iron-work of the door to the contents of the safe. The hinges are annealed and are riveted to the outside of the door and the front plate. The main object of the improvements in this safe is to prevent opening of the joints, due to warping of the frame. The latter is made of solid forged metal, and in fact is a continuous, four-sided angle-iron, constructed of a suitable size to fit over and receive within it the back portion of the outer walls of the body. It has a slot in its lower side to receive a back plate, which, after being slid to its place, Fig. 11, is secured by a separate bottom piece, closing the gap in the bottom of the angle-iron frame, and is in turn fastened by rivets to said angle-iron frame. The back plate is further secured by fastenings passing through the outer angle-iron frame, through the back plate, and entering an inside system of angles. The continuous angle-iron frame prevents the fire-proof filling working out through the joints, and strengthens the safe.

Sampler : see Ore Sampling.

SANDPAPERING MACHINES. Sandpapering machinery, with which may be included finishing machines using sanding belts, and sanding cylinders and cones, are of great variety, according to the class of work which they are to perform. The function of all is the same: to remove roughness and produce a smoothly finished surface. Their action is often supplemented by polishing attachments, which put upon the wood a luster, and give it a smooth, velvety feel which mere sandpaper or its equivalent could not impart.

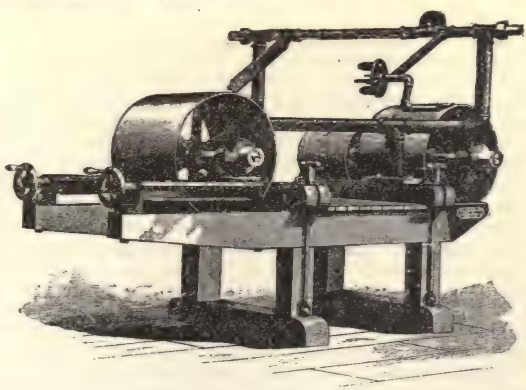


Fig. 1.—Sand-belt machine.

The sand-belt machine shown in Fig. 1 is for polishing the body of wagon and carriage spokes, and also for finishing neck yokes, single trees, handles, and similar articles. There are two sand-belt pulleys, having parallel horizontal axes, the distance between which may be regulated by hand wheels and screws ; the article to be polished is held between centers supported by radial parallel arms, swinging on an axis parallel with those of the belt pulleys. One of these centers may be turned by a hand crank, so as to present every side of the piece in succession ; the other is a dead-center.

Another type is known as the bracket machine, being designed to attach to a wall or post. There is a bracket bearing a vertical pulley spindle, and a hinged arm, the outer end of which has a vertical spindle, on the lower end of which there is a drum covered with sandpaper upon its lower head. The rotation of the sandpaper drum, and the traverse of the hinged arm in every direction in a horizontal plane, enable the machine to cover the entire surface of a door, or similar plane piece, and at the same time do work that is reasonably free from scratches. The sandpaper disk is vertically adjustable to different thicknesses of stock, and has a spring handle to regulate the pressure on the surface, and a suction fan to carry away the dust. Another form of this machine has, instead of a bracket, a column placed near a cast-iron table, upon which the door or other piece is placed, and the hinged arm has more joints. In the column is placed the exhaust fan.

Another machine has a single vertical spindle, bearing a plain cylindrical drum or tube of small diameter, covered with sandpaper on its convex surface, and is useful for finishing the internal and external curves of scroll-sawed work. The spindle in the best of such machines moves automatically up and down by a crank and pitman, as it rotates, so as to free the surface of the work from scores. A development of this type has two such spindles, placed about 3 ft. apart, and one bearing a large and the other a small cylinder or tube, these working in curves of either large or small radius. In these, each spindle has a vertical reciprocating as well as a rotary movement; the former being produced by cranks at each end of a shaft, running across the frame at the bottom of the spindles.

A triple-drum sandpapering machine, shown in Fig. 2, is for sandpapering planed sur-

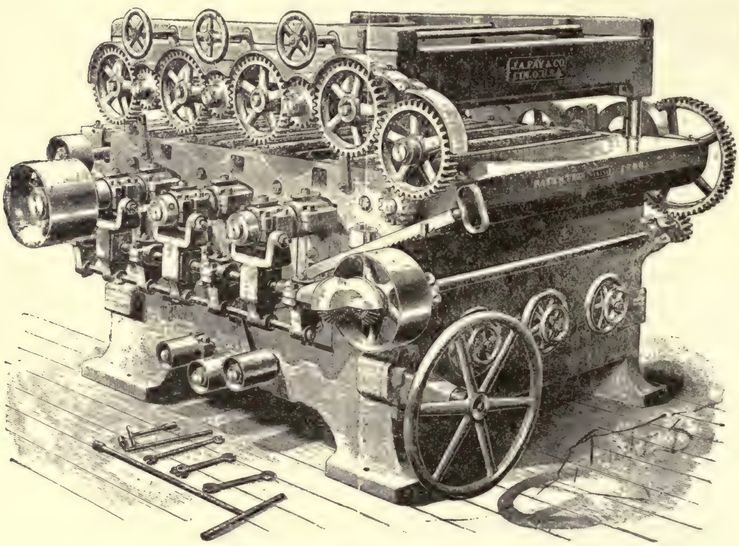


FIG. 2.—Triple-drum sandpapering machine.

faces for furniture, pianos, etc., where the work is to be varnished or painted. There are three drums, made of steel, on which the sandpaper is placed, its grade being according to the work to be done. The first drum carries coarse paper, the second a fine grade for smoothing, and the third a finer grade for polishing. Each of these drums has lateral oscillation across the material, to prevent the formation of lengthwise scores, which would be the case if the material moved straight, and the rolls had no such endwise vibration. The feed rolls are eight in number, four above and four below the platen, and are driven by a train of expansion gearing. They are so placed that the material will pass between the upper and lower sets, and open to receive material 8 in. thick. The lower rollers are placed one each side of the drum, each roller being in a separate bed-plate, which is adjustable with the roller, and the roller has a separate adjustment from the bed-plate. Each bed-plate can be set to gauge the amount of cut to each drum, or all the bed-plates can be set in line, and the drums set to the cut desired above this line. The upper rollers are mounted in a frame over the corresponding lower rollers. The pressure rolls are three in number, one over each drum, to hold the material firmly to them, and are separately adjustable by hand wheels in front, which operate worms and worm gears.

There has been produced one machine which will joint and sandpaper the meeting rails of sash. The sash is placed on a movable carriage, with the meeting rail resting against adjustable stops, by which a heavy or a light cut may be obtained, as desired. The sash while passing through the machine is held in position by springs, by which means the meeting rails are worked to the same thickness. The jointing is done by a rotation cutter head on the vertical axes of one side of the machine, and the sandpapering head or drum is borne by a

horizontal shaft, which springs its working surface practically in line with that of the cutter heads. The capacity for jointing and sanding is eighty windows per hour. There is a plowing and boring attachment, the sash being placed against a gauge on the lower table, at an angle of about 30°, and the stile bored with one bit to receive the cord. The sash is then placed against a gauge on the upper table, and grooved or plowed to the hole, so that the cord can be heavily knotted and slipped into the hole, and the weight of the sash will draw the knot to the bottom.

Sand Wheel : see Ore-dressing Machinery.

SASH MACHINES. Wood-working machinery includes not merely machines for cutting material, but those for clamping, bending, etc. Sash and door manufacturers make use of machines which clamp up sash, and, where they are glued, hold them while the glue is drying. One variety has heavy plate sides and guards, and on the top there are two heavy rails, in which are mounted corner bars for holding the sash. These are pivoted to traveling plates, through which pass right and left-hand screws, by which each corner can be moved an exact distance from the center, and at the same time remain in a fixed rigid position. A pressure of the foot upon a treadle secures and clamps the sash. The arrangement of lever connections is on the toggle principle, by which the greatest power is applied just as the joint is closed, or where there is the greatest resistance. The same machine modified for door clamping has a supplemental treadle which releases the door, and allows the clamp to open.

In the door and sash clamping machine made by the H. B. Smith Machine Co. there are two draw-bars, and very short stiff compression members ; and the lever connections form a knuckle-joint, which in use just passes a central point, thus retaining the clamp in position until released. The fulcrum of the treadle which actuates this toggle and clamps the frames is adjustable so as to make more or less movement on the clamps, as may be required. Each receiving rail has long dogs for doors, and short ones for blinds. For sash clamping, there are employed four corner dogs, pivoted on iron plates which may be fastened on the machine.

In a relishing machine brought out by the H. B. Smith Co. there is a square main

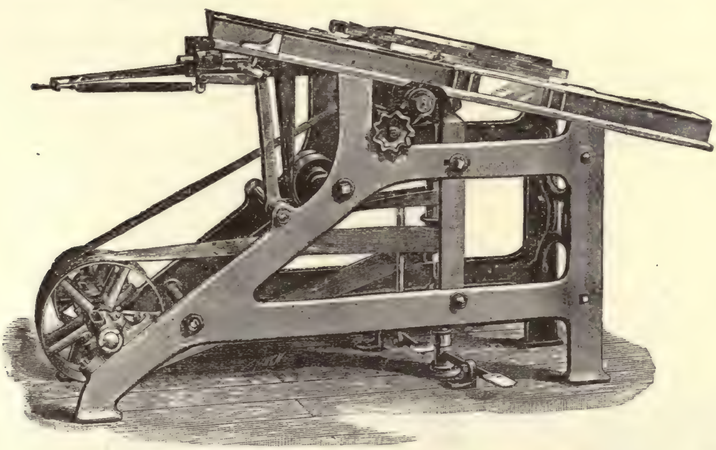


Fig. 1.—Sash, boring and plowing.

table, bearing a mandrel upon which there are two sets of saws, one at each end. There are attached to the main table two glued up wooden tables, borne by brackets, and having vertical adjustment, as also sliding motion to and from the saws. The rail is first placed on the left-hand table, which is shoved back to the saws, making the angling cut. It is then placed on the right-hand table, which is shoved back to the saws, and then by a treadle the right-hand table bearing the stock is raised, to meet two small circular saws borne by horizontal mandrels at right angles to the main saw arbor. These cut the relish, and the wedges drop into a box or basket on the floor. The angle, width, and depth of the relish are regulatable by gauges and stop dogs.

A special machine. Fig. 1, for sash boring and plowing, intended, as its name implies, for the preparation of window sash for the reception of a cord, does plowing in two ways.

In the first system, it is adapted to bore a hole of suitable size into the edge of a sash, and at an angle of about 30°, and to plow a groove of suitable width and depth, connecting with this hole. Into this groove and hole a suitably knotted cord is placed ; a draft upon this cord draws the knot into the slanting hole, and holds it in position.

In the second system, a 30° angle hole and slot are formed, as in the first instance, but the slot, instead of being cut to connect with the hole, is cut to within an inch thereof, and then by a hole bored by a second bit of suitable size and arrangement the slot and angular hole are connected, and the sash cord drawn through this latter hole, and knotted in the

angular hole. The one feature of this machine is that in making stock work, where it is uncertain whether the sash will be used with or without cord, the groove can be discontinued at the meeting rail without cutting through it, and this part done by hand if the sash is finally used with cord.

The increasing demand for sash and doors all ready to hang has brought out machines for preparing sash to receive the weight cord in a manner to suit the requirements of all markets ; the old method of a groove in the side of the sash, running through a hole that carries the knot on the end of the cord, often being very unsatisfactory. In the machine made by the H. B. Smith Machine Co. there is a table-like frame, bearing along one of its sides a horizontal boring spindle, and having a sliding frame to receive a sash and feed it up to the spindle. A double saw borne by a vertical arbor about the center of width of the machine, cuts a groove which extends into the top or first hole previously bored by the bit, and the work is then completed by the horizontal boring bit, making a hole between the two holes first bored, thus uniting the second or lower hole to the groove. The cord may be very readily passed into this hole, with no chance of getting out after the knot is tied.

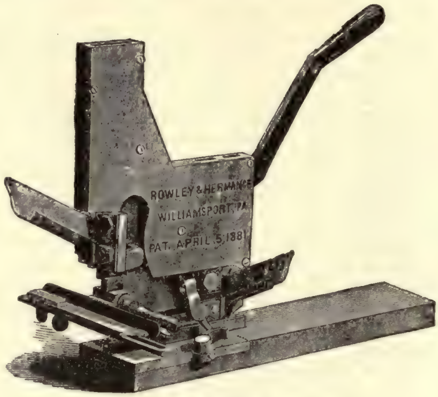


Fig. 2.—Sash wiring machine.

The same machine may be used as a light saw table, with horizontal boring attachment for general purposes ; and by using a routing bit in the vertical spindle, blind-rails may be scored for the roller bar.

A machine for wiring both blind-rods and their slats at one operation is shown in Fig. 2. The slat is placed on the upper bed, and by an upward motion of the lever the staple is driven in. Then the same slat is placed on the lower bed, and a downward motion of the same lever staples the slat to the rod. The staple cut-off is so arranged that two staples cannot get under the driver at the same time.

Saw Gummer : see Grinding Machines.

Saw, Pile-cutting : see Pile Driving.

SAWS, METAL WORKING. *Cold Saw Cutting-off Machines.*—Sawing machines for cutting iron, steel, and other metals while in a cold state have come into use during the past few years. They are probably more commonly used in Europe than in this country at present, but

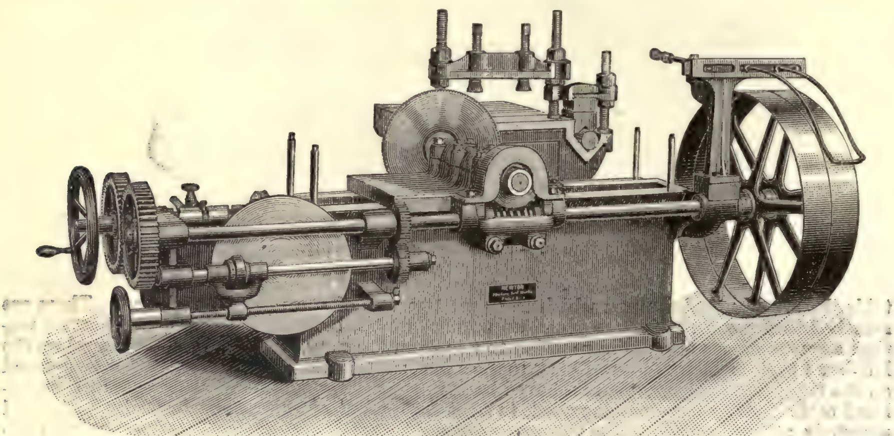


Fig. 1.—Cold saw cutting-off machine for bars and beams.

the Newton Machine Tool Works, of Philadelphia, have recently put on the market a full line of these machines of various styles, and their more general use may be anticipated. Several styles of cold saw cutting-off machines built at the above-named establishment are shown in Figs. 1 to 4.

Circular Saws.—Fig. 1 is a machine designed to cut off round or square bars up to 4 in., and beams up to 16 in. in depth. The saw or mill cutter is $18\frac{3}{4}$ in. in diameter. It has a variable automatic feed, ranging from $\frac{1}{2}$ in. to $1\frac{1}{2}$ ins. per minute, with power quick return, with automatic stop in both directions.

Fig. 2 is a machine designed for trimming the edges of armor plate after it comes from the rolls. The machine will cut work up to 10 in. in height and 13 ft. long. It is built so that it can be used as two independent machines, or can be adjusted to take in work between saws 20 ft. in width. The work tables are made narrow so that the two machines can be brought together within 30 in. of the saws. The work table of the adjustable head can be removed, so that work of the width of 15 in. can be cut, both sides at one time. To support the outer end of the armor plate, the entire machine is provided with a table planed the same height as the work table on the machine, and if the plate is wider than the clamps will admit, it can be clamped with bolts on the outside work table. The clamps can be readily removed for convenience in setting work. The machine is set on cast-iron girders, allowing one head to be adjusted by power in and out from the stationary head. The saws of the machine are 36 in. in diameter.

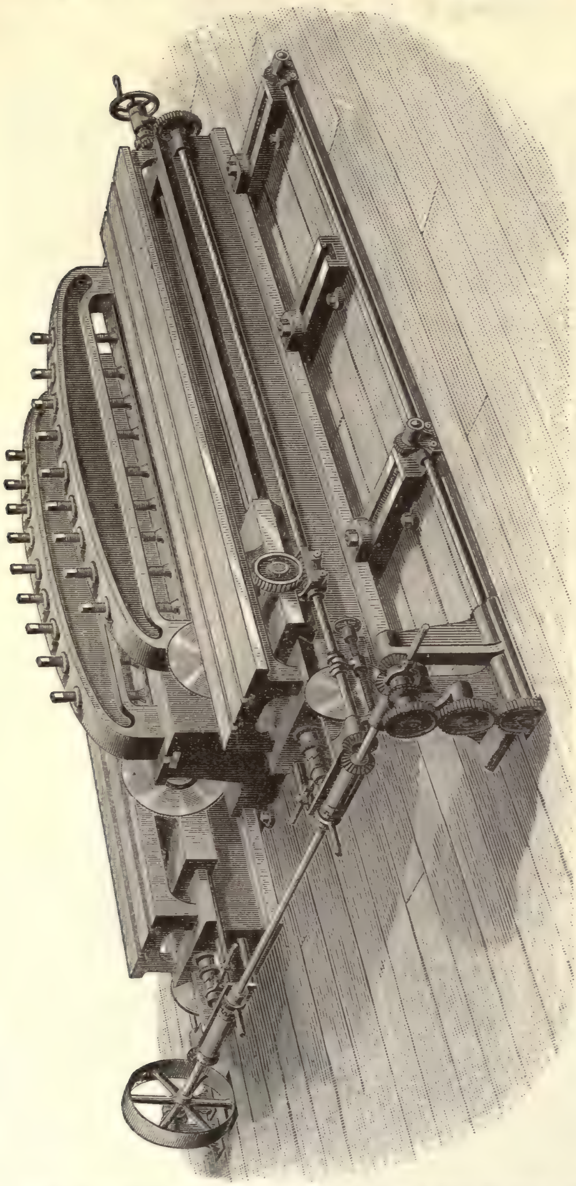


Fig. 2.—Cold saw machine for trimming armor-plate.

Fig. 3 is a cold sawing machine which is set on a turn-table, and driven from the central point underneath the bed, so that it can be swung around at any angle. The advantage of this tool for heavy work lies in economy of shop space.

Fig. 4 is a machine for cutting round, square, and flat bar. The work to be cut off is laid on the work table and clamped. The saw is then fed down through the bar, cutting off the same as on the ordinary machine. To lubricate the saw, the machine is furnished with a small pump and connections, throwing the lubricant on both sides of the saw. The machine has four changes of feed, with quick return by hand. The arm of the saw is counterweighted to overcome any tendency which the weight of the arm would have to press the saw against the work, as it is necessary for the success of these machines to feed them positively, and not in any way by any gravity contrivance. The saw being fed in this manner can be forced into the work, and the work cut off very quickly. The machine can be used not only for cutting off bars of iron and steel, but also for cutting off small beams, making the cuts square, and can be used on beam work to any angle within the range of the machine.

Saw Grinder.—Fig. 5 shows a grinding machine furnished by the Newton Machine Tool Works, for grinding the teeth of the saws of their cutting-off machines. The saw is placed on the arbor, and the saddle is adjusted to suit the diameter of saw; the emery wheel, the face of which is given the profile of space between teeth, will then, when passed over the saw, grind the face and top of tooth at one time. The spring trigger, or catch, is set to suit the tooth of saw, which is revolved by hand, one tooth at a time, the trigger guiding the saw. When the saw is ground in this manner, it will always retain the shape of tooth, and keep the saw round.

Horizontal Circular Saw.—Fig. 6 represents a cold sawing machine, designed by Messrs.

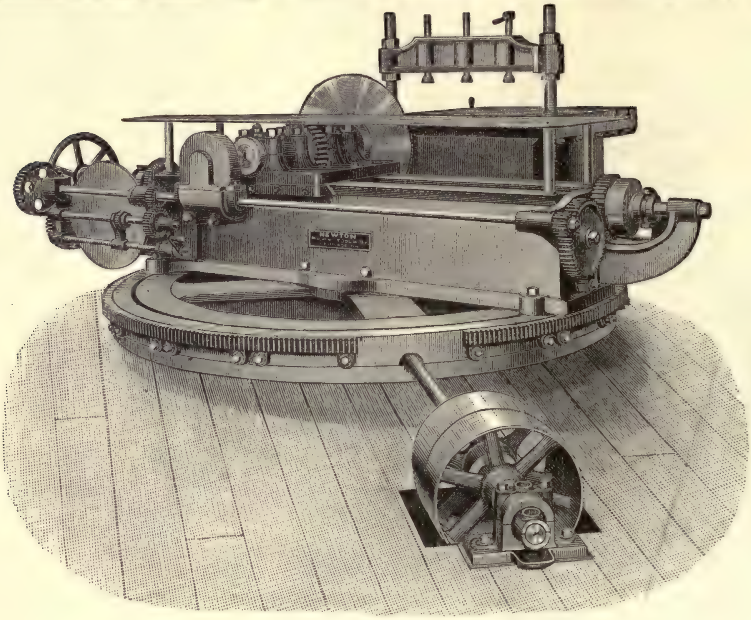


FIG. 3.—Cold saw cutting-off machine built on revolving bed.

Isaac Hill & Son, Derby, England, and used principally for the sawing of runners or gates of steel castings. The saw is caused to revolve in a horizontal plane, and in the case of the

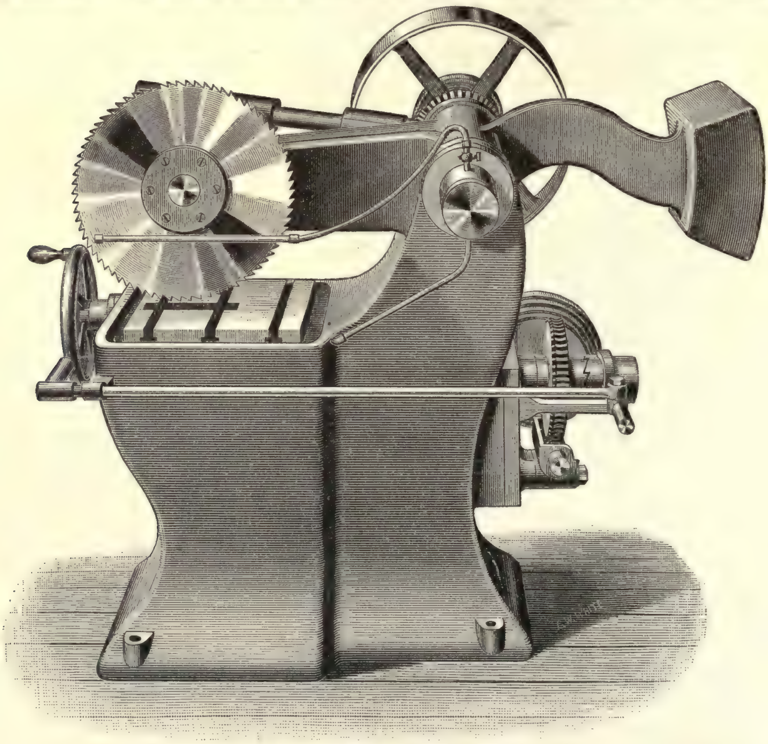


FIG. 4.—Cold saw cutting-off machine.

machine illustrated it may be raised to 3 ft. 6 in. The machine carries a 28-in. diameter

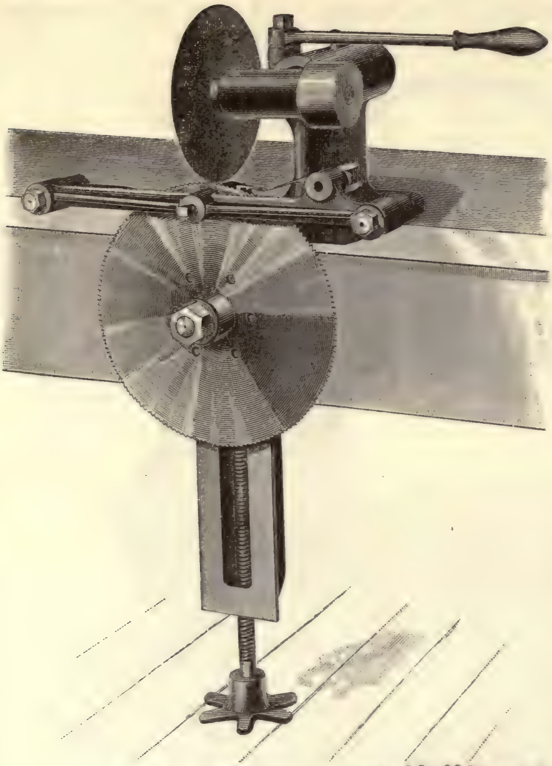


FIG. 5.—Saw grinder.

saw, having a longitudinal travel of 16 in., and will cut solids up to 8 in. thick. The saw is secured to the spindle by a flush side arrangement, while the driving is by a type of gearing dispensing with the usual worm and worm-wheel. The feed is self-acting, of three speeds, and suitable for sawing solids, for quick return motion, and for disengaging motion, there being an automatic gearing for disengaging the gear clutch at any point in the forward or return traverse. The slide bed upon which the saw-carrying saddle moves has a traverse slide which fits the standard. The raising or lowering is done by hand through a worm and worm-wheel, by a wire rope carried on suitable carrying pulleys on a drum; while the exact lowering or raising adjustment of the saw is done by means of a telescopically arranged spindle. The driving is from the main shaft onto pulleys on an overhead shaft carried in bearings across the top of the machine. Upon this latter shaft is a bevel pinion, which gears with a bevel wheel supported on a bearing as shown, this bevel wheel communicating motion by a feather key to the vertical shaft, which can slide through it. On the low part of this shaft is secured a bevel pinion, which gears with a bevel wheel on the principal shaft of the sawing portion of the machine.

Band Saw.—Fig. 7 shows the Newton band sawing machine, which can be used to advantage in cutting the center out of cranks, connecting rods, piston rods, eccentric rods, pump levers, etc., and for cutting curved or irregular work, where it can be guided by hand. The machines have a large stationary work table, the rear section of which is made so that it can be moved away from the saw, so that the saw can be removed from the pulleys. The automatic feed table is inserted in the stationary table. The saw wheels are covered with a rubber tire, and the

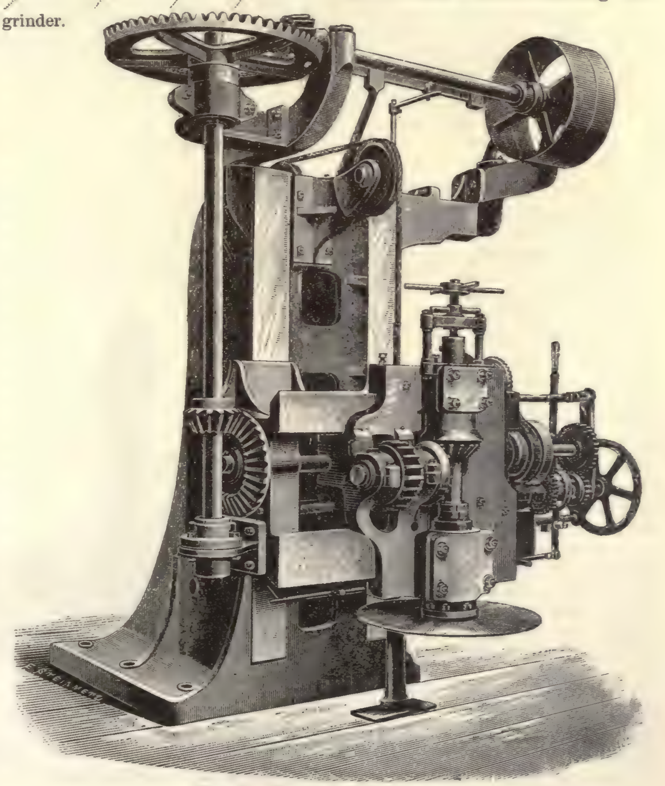


FIG. 6.—Horizontal circular saw.

bottom wheel runs in a bath to lubricate and cool the saw. The upper wheel is provided with a suspended bearing, with attached weight to keep the saw at a proper tension. The

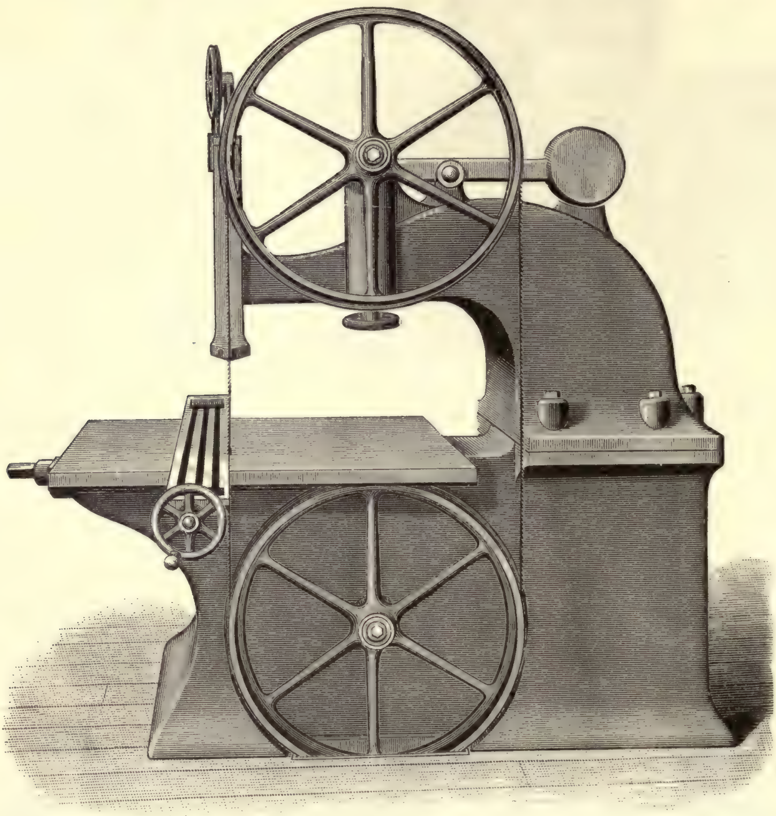


FIG. 7.—Band saw.

saw passes between two guides and presses against a wheel which revolves with the saw, thus reducing the friction. The lower saw guide is inserted in the table, and the upper guide can be raised and lowered to suit the various depths of work.

SAWS, WOOD. In the consideration of sawing machines, we may divide them into straight, circular, and band; the former being either strained or unstrained; the circular type existing in great variety, according to the number and disposition of saws, and the purposes for which they are intended; and the latter, while having no such range as those of the circular type, still requiring different treatment, according as they will have light or heavy work, and will be used for ordinary cutting, scroll work, or resawing.

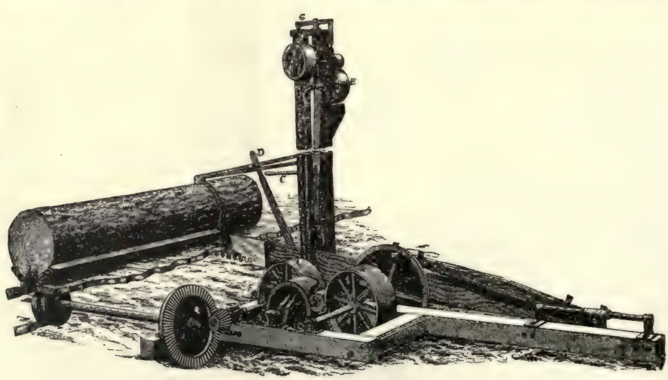


FIG. 1.—Drag-saw and jack-works.

STRAIGHT SAWS.—In the first class, that of straight saws, there is but little to offer at this time in addition to what has been said about them in the preceding volumes; but there may be noted a combination of drag-saw and log-jack

or jack-works, Fig. 1, which is intended to save room and lessen the number of frames to set and belts to keep in order, while but one lever is required to handle both machines. In operating it, the sawyer throws the lever over until the paper friction bears against the log-jack friction-works enough to draw the log to its place under the saw, the requisite distance of lengthwise feed of the log ; then the lever is thrown further over until it bears upon the drag-saw enough to drive that at the speed desired. The log-saw and the jack cannot be run at the same time. In order to rest the drag-saw, the operator presses down upon a short lever, which forces together two overhead frictions, and so winds up a belt connected to the side piece of the drag-saw. Releasing the short lever permits the weight of the saw to pull the iron friction of the saw down tight on the brake under it and hold the saw in that position. By slightly pressing the short lever the saw will descend slowly.

CIRCULAR SAWS.—In taking up the subject of circular saws, we may first consider the log-mill, board-mill, and resawing machines, these being the first in order of action upon the wood, in its conversion from the log to the finished product, no matter what it is. As circular saw-mills have been treated at considerable length in the preceding volumes, it may be desirable in this place only to note special forms of this wonderful factor in wood conversion, and to mention some of the appliances and attachments which give it greater range of dimensions and character of output, and better quality of work, coupled with great increase in the amount of material that can be handled in a given time.

Circular Saw-mills.—A very great advance in the circular saw-mill is making it double—that is, with two saw arbors, one above the other in the same vertical plane, the upper one bearing a smaller saw than the other, both saws cutting in the same vertical plane. The upper arbor is given vertical adjustment on the housing, to enable it to be raised and lowered to suit variations in the diameters of the saws. The upper saw is driven from the arbor of the lower one, usually by an open belt, so that both saws, as regards the spectator, rotate in the same direction ; but as regards the lumber, the teeth of the upper one enter it in the direction opposite to those of the lower one, the teeth passing each other in opposite direction. The saws are set so that the periphery of each one intrudes a trifle upon the kerf or channel made by the other, one of them being a little in advance of the other to enable this to prevent the teeth of one saw interfering with those of the other. The upper arbor is for saws having the same holes as the lower ones, so when the lower one is worn too small for effective service it may be used as an upper one, and the upper one moved to a smaller mill. As smaller and thinner saws are used than on single saw-mills, they can have, and really require, faster feed ; they cut a thinner kerf, are more readily kept in order, are less liable to accident, and cost less to replace when broken. As the speed of the smaller saws is higher than that of one large saw, the feed and gig motion of the double mill are higher than those of the single.

As some sawyers desire that the upper saw in a double circular mill shall run reversed, and as a quarter-twist belt would be impracticable, by reason of the short distance between arbor centers, such a direction of motion is got by having the belt run from a pulley on the lower arbor, over an idler pulley above the upper mandrel, down under the pulley on the upper arbor, up over another idler, and down under the pulley on the lower mandrel. This produces the effect of a quarter-twist belt, with full facility for varying the tension, and gives better contact upon the pulleys, as the idlers are quite close together, so that the belt gives more than 180° wrap on the upper saw pulley. It is desirable to have a device for guiding the rim of the saw near the cut, to prevent it from straying out of the true plane ; and this guide must be adjustable toward or from the saw arbor to suit various diameters of saws, and also must have adjustment to suit the varying gauges of different saws, and also the varying thickness of the same saw, as it is worn down in diameter. In addition to this, there must be a certain amount of adjustability to and from the line of the carriage, to accommodate different thicknesses of collars, etc., as well as different conditions of saw tension. All these adjustments should preferably be made without the use of a special wrench, and should be of such a character that they may be done quickly.

One of the best of these consists in effect of two horizontal and parallel hollow cylinders, in each of which turns a wrought-iron pin, adjustable lengthwise of the bore containing it, by a screw and milled nut. One of these, when nearest the saw edge, is terminated by a short arm bearing an anti-friction piece, which guides the inner edge of the saw disk. The outer bears a longer arm, having a smaller anti-friction piece, which may be brought into contact with the first, or withdrawn by means of the saw or milled-nut arrangement. This second bar and arm engage and guide the outer face of the saw disk. The entire device is fastened by screws and milled nuts to a slotted piece borne on the saw frame, thus permitting lengthwise adjustment to suit saws of varying diameters.

Back of the saw, in a log-mill, there is, or should be, what is known as a spreader or splitter wheel, which in the best makes is thinner in the middle than near the edge, to lessen friction. The shaft bearing the splitter is supported in hangers, and on it is a large roll, which supports the lumber passing over the frame ; but the roll and the splitter plate rotate independently of each other, this arrangement preventing accident by reason of a heavy stick of timber resting on the shaft, preventing the splitter-wheel from turning.

The carriage of a circular saw-mill of the first class consists essentially of two long side sills or timbers, framed together by iron cross beams above, and which bear on its under side iron facing pieces, which bear on rollers placed at suitable distance on cells in the floor of the mill. Carriages are usually made in sections of about 15 ft. in length, and fastened together by rods and dowels. The side piece nearest the saw bears on its under surface a

rack that engages with a pinion by which lengthwise feed of the carriage and log are given, driving the saw through the log.

In some mills this rack-and-pinion feed is dispensed with and a rope feed is used; in others the carriage is connected to the piston-rod of a long steam-cylinder, and admission of steam drives out the piston and forces the carriage along by direct action at a marvellous rate of speed; this constitutes what is known as a "shot-gun feed." Lengthwise of the carriage, on the side furthest from the saw, is what is known as the set-beam, which is prevented from springing up by suitable projections engaging with the under sides of the cross pieces of the carriage. To this set-beam there are attached the various head and side blocks and uprights to which the log is attached or against which it rests. The set-beam, blocks, uprights, and log are given traverse across the carriage by slight advances each time that the saw has made a cut and the carriage is drawn back; the rate of withdrawal being much more rapid than that of feed, even with the shot-gun feed. The set-beam is advanced only a slight degree after each cut; and in large mills it is retired by power to make room for the next large log after one has been sawed down to the last board.

The rack-and-pinion carriage feed has the disadvantage that the teeth of the rack and pinions are liable to break, causing annoyance and delay. To lessen this trouble, it is necessary to increase the width of face of the gears, which of course adds to the weight of carriage. Where rope feed is used, there are several ways of effecting the winding up of the rope. In one of them, which may properly be called a rope and gear feed, the rope sheave is made in the form of an internal gear, having the cogs or teeth on the inside and the spiral groove for the rope outside. This sheave is keyed to a short shaft, which runs in boxes bolted to the timbers underneath the carriage and directly opposite to the mill frame. It is rotated by a feed pinion which runs in the internal gear in the same manner as it would in the rack of the carriage.

Some sawyers prefer trucks on the carriage and tracks on the floor, but this has disadvantages, in that tracks on the floor obstruct the floor itself, and dirt on them is readily accumulated and is likely to throw the carriage off the track or lift it on one side, thus making an irregular cut. A carriage with the track on its under side is lighter than one bearing trucks; it runs more easily; the rolls may be more readily kept in line and level than a track; the chairs which bear them may be set on a level with the floor of the mill, enabling it to be crossed with barrows, etc.; they are more durable, because only such rolls as the carriage passes over rotate, while where they are on the carriage every one turns; they are more readily replaced when worn, and are more economical, because when those opposite the saw frame, which are most used, are worn, they can be exchanged for those nearer the ends; and the back rolls being finished the same as the front ones, can be changed to the front and made to do service as guide rolls.

In the best mills the head blocks and horizontal rests on the carriage are at intervals of 3 to 4 ft. the entire length of the carriage, and uprights which add side support are placed on the set-beam directly over, and at right angles to, the head blocks. This arrangement does away with the necessity of moving the head blocks when sawing logs which vary in length.

Saw-mill Attachments.—Dogs for holding the logs are sometimes merely steel rods, having heads like pointed hammer-heads, one end of the rod being fastened by and on to the set-beam, the other end being driven into the log. But those on head blocks and tail blocks are more complicated, being arranged so that two of them bite into the upper and under surfaces of the log in opposition to one another, being forced in by screw or eccentric motion. For enabling the saw to work close up to the uprights, there are what are known as last-board dogs, which project only about one-half inch from the uprights, and may be used after the other dogs have been retired by reason of the log having been nearly entirely sawed away.

A saw-mill dog, brought out by the Knight Manufacturing Co., of Canton, O., belongs to that class in which an adjustable head carries the dog-bit, and is secured at any point on a horizontal sliding bar, with a lever connection to force it into the timber. The upright is formed of two parallel straight pieces, on one of which slides the head carrying the upper dog-bit, giving adjustability in height; the locking mechanism for this being an eccentric and lever. The lower dog is inclined at an angle of about 45° with the vertical, its lower end being turned up to about the same angle. It is controlled by the lever which operates the upper dog. The lower dog-bit moves upward until it strikes the timber, then upward into it, both dogs being locked in position when first in the timber. To operate the upper dog, the dog-bit is dropped on the log, and is forced downward into the timber by drawing downward upon the long lever. When released from its bite in the timber, the lower dog returns to its original position, automatically locking itself, and remains there out of the way until again liberated by the operator. These dogs are made right and left-handed. For a right-hand mill a right-hand dog is used on the front head block, and a left-hand one on each rear block; while on a left-hand mill a left-hand dog is used on the front head block and a right-hand on the rear.

For holding quartered logs on the carriage there are employed what are known as quarter-log dogs, which have two sets of teeth, sliding up and down on the upright, and each set arranged so that their points come in a vertical line, inclined about 45° to the horizontal, so that they can conveniently grip between them the corner of a quarter log, included between one of the sawed faces and the bark.

For rolling heavy logs on to the saw-mill carriage, and for turning them when slabbing, it is almost necessary to have a canting machine of some sort or other. One of the most simple, which may also be used for drawing logs into the mill, consists merely of a horizontal

drum, on the axis of which there is a spur wheel, driven by a pinion on a shaft, receiving power by belt. This device, when used as a log turner, is fastened to the timbers overhead, and a chain attached to the drum is carried along over open sheaves to the middle of the carriage, as it stands when run back to take on the longest sticks. In turning, the sawyer or his assistant takes down from overhead the hook which is attached to the chain and attaches it to the log, and by throwing on the belt-power causes the chain to wind up on the drum, and thus turn the log as much or as little as desired. Logs may be rolled from the log deck by passing the chain entirely around them once or twice, and then working as before mentioned. When used as a jacker for hauling in logs, there is required a longer spool, heavier gears, and longer chain, and the machine may be placed either under the mill floor, or overhead, as may be most convenient. The gearing and frictions should be heavy enough to enable several logs at a time to be hauled into the second story of a mill building.

One very well made log-jacker has an endless chain engaging with a pitch wheel and a shaft which is driven by spur and pinion, the shaft bearing this latter being driven by V-frictions from a belted shaft.

A log-nigger moves the log from the table to the carriage, by a nearly vertical beam, pivoted at its lower end beneath the mill floor, and given slight oscillation in the direction in

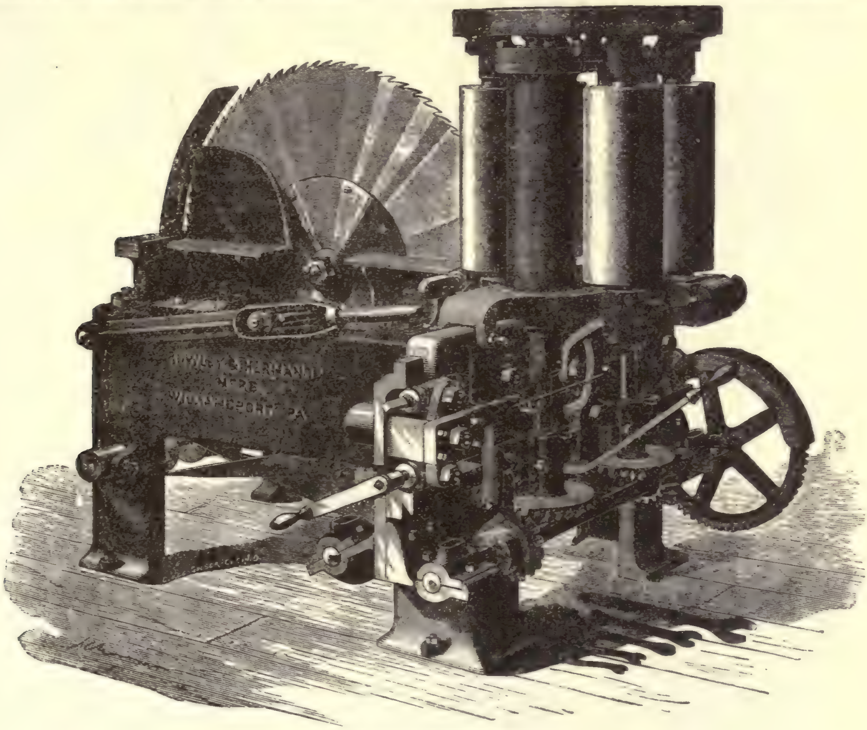


FIG. 2.—Resawing machine.

which it is desired to move the log, by a friction device hauling on a chain. The upper end of the beam next the log is armed with teeth which engage the logs.

A gauge-roll for board-sawing machines consists of a vertical roll on a horizontal bracket, which slides along a horizontal graduated scale, so as to bring the vertical roll at any distance from the saw, the motion being effected and the position of the roll maintained by the screw mentioned, and a hand wheel. A scale shows the actual distance between the saw and the roll. A horizontal roll at the back of the device serves as a support for the lumber passing over the frame. The arm which bears the vertical roll is hinged so as to swing out of the way when slabbing. The special use of such a roll is in sawing boards of different thickness, such as is known as dimension stuff, and in making the last cuts through a cant, as it prevents the lumber springing away from the uprights, and increases the evenness of thickness of the lumber.

Resawing machinery has taken a very important place in the economy of sawing. It has now become the custom almost all over our country to saw the logs at the mill only into standard dimensions of considerable size, and to ship these to near the place of distribution and consumption, where they are then sawed thinner, to such dimensions as may be considered most desirable for the local market or special demand. This policy greatly lessens the waste of lumber, in that the kerf taken by the resawing machine in slitting a plank into two boards is less than that made by a heavy log-saw, and also there is less material spoiled by the grit,

dirt, and defacing marks which are inseparable from shipment by rail, canal, or raft. The light and rapid resaw also enables a dealer to fill his orders for irregular thicknesses, or for any great quantity of any regular size with reasonable promptness, and without having to keep on hand, drawing interest, and subject to fire risks, an unreasonable stock of lumber.

The resawing machine shown in Fig. 2, and made by Rowley, Hermance & Co., of Williamsport, Pa., has a heavy frame cast in one piece. The arbor overhangs the box next the saw, admitting of the latter being easily removed. The saw arbor boxes are connected by a heavy yoke and keyed to the frame, and are moved to and from the rolls by a screw, keeping the saw in line with them. The rolls move upon the platen in pairs and adjust themselves to various thicknesses of lumber, opening 6 in. and permitting a 1-in. board to be cut from a 6-in. plank. One pair of rolls may be made stationary, and lumber of even thickness cut upon that side, and inequalities of thickness confined to the other side. The table upon which the lumber rests being very close to the rolls, permits of sawing very narrow boards. The feed works are reversible, and lumber may be run from the saw more rapidly than to it. The platen that supports the rolls turns upon a center for sawing beveled siding, and is regulated by a graduated index plate. The saw may be lifted out of the frame and kept suspended on a pin in the center, thus protecting the teeth from bending and twisting.

The 24-in. circular resawing machine shown in Fig. 3, and made by the Egan Co., is for beveled siding and general planing and furniture work. The frame is one piece, cored out. There are four vertical feed rolls, which work so close to the board rest that a $\frac{1}{2}$-in. strip may be cut if necessary. The feed rolls are on a swinging frame, and by the adjustment of a hand nut any angle of cut may be obtained. The feed rolls are carried together, and the belt which drives them runs from the middle to the countershaft, and from that to the cone pulley on the feed shaft, so that when the feed rolls are thrown on a bevel the feed belt keeps its tension. The feed rolls may be moved all four at once, or only two at a time. There is lateral adjustment by a crank at the end. They are self-centering, and will take any lumber from $\frac{1}{8}$ in. to 8 in thick. Those on one side may be made rigid by a crank handle at the side of the swinging frame, to permit of taking a piece $\frac{1}{4}$ in. thick from the side of a thick plank.

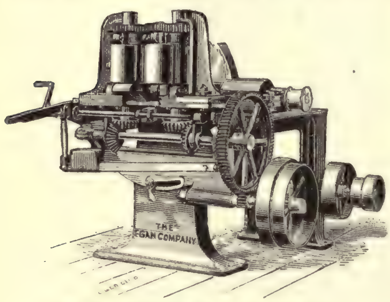


Fig. 3.—Circular resawing machine.

In a resawing machine made by Hoyt & Bro. there is an iron trough which nearly follows the lower periphery of the saw, and merges into a spout which conducts the sawdust clear of the machine, or to a chute or exhaust pipe, thus materially adding to the convenience of the machine.

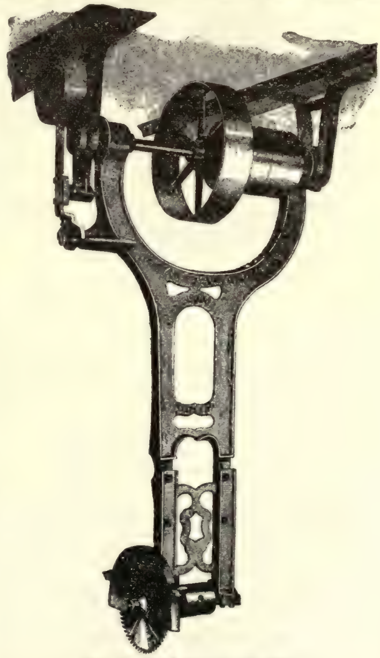


Fig. 4.—Swing cut-off saw.

For the larger grade of resaws, the saws are sectional, having thin sectors fastened by flush screws to a tapering central disk ; the adjacent radial edges of the sectors being joined by dovetail pieces flush with the edges of the plate, and close to the tooth line. Of course, this permits the use of thinner saws than would be possible where a single disk was used.

Various Forms of Circular Sawing Machines.—Of circular sawing machines other than those for log-cutting and board resawing, there are many varieties, distinguished or classifiable according as there is one or more than one upon the table, and whether, where there are two, these are parallel and upon the same axis, so that both may be used at once, or are on separate arbors, so that only one may be swung into use at once. In some machines, too, the work is fed to the saw ; in others the saw is fed to the work ; and in those in which the saw is stationary, the work may be fed by hand, or drawn along by a chain upon rollers, or fastened to the carriage and moved with it. In those machines in which the saw is moved to the work, it may be on a carriage or saddle, or swinging at the end of a pendulum. Where it is on a carriage or saddle, its motion may be either horizontal or vertical, and if at the end of the pendulum it may be pivoted either below or above the work. All these varieties exist ; each of them having some special purpose, and being best adapted for that purpose. Some sawing machines are for ripping, others for cross cutting ; some for gaining or grooving as well as for separating.

Bracket stationary cut-off saws appear in two principal varieties, one in which the bracket is fastened to a post or wall, and another in which it is borne by a special cast-iron column. The bracket has a vertical adjustment upon the column, where there is one, and upon the wall plate where there is no column. The arbor runs horizontally in a sliding gate-way gibbed to the face of the bracket. The table bearing the work is at right angles to the bracket and has rollers to facilitate feeding along the stuff. The table has vertical adjustment by hand wheel, to suit the thickness of the material being cut or the wear of the saw to smaller diameter.

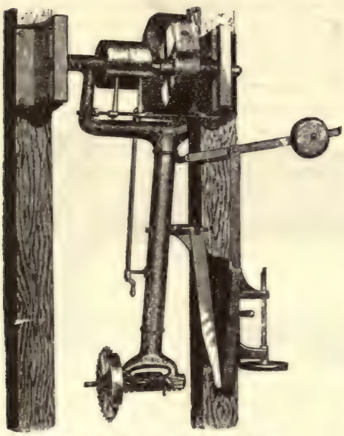


Fig. 5.—Parallel swing saw.

A vertical cut-off saw made by the Berry & Orton Co. has a vertical column, up and down one face of which there slides a counterbalanced saddle bearing a saw mandrel ; and its movement up and down, which is by a rack and pinion, is controlled by a treadle. The table which bears the work has adjustment to and from the column to suit different diameters of saws, and also radial adjustment for angle sawing. The same machine may be used for gaining if desired.

In a direct-acting steam cut-off saw by William E. Hill & Co., the circular saw and its mandrel are on the top of a solid iron frame, planed on its side and edges, and working in adjustable vertical guides. This iron frame is worked up and down by an upright steam cylinder with 28 in. stroke, and having steam cushion at each end to permit of high speed of working.

A powerful machine for cutting off and gaining, as in railway, car, bridge, and other heavy work, has a vertical column from which there projects a strong horizontal bracket, on the under surface of which there slides a carriage bearing a saw with horizontal mandrel. Under, and at right angles to this bracket, there is a horizontal table at which is placed the material to be cut off or gained ; this table having rollers to permit the material to be moved lengthwise to bring the proper mark under the saw. To provide for the use of circular saws of various sizes, and to allow for the cutting of gains of different depths, the arm or bracket is adjustable vertically by screws operated by hand or power. The saw carriage, which traverses the entire length of the arm, is moved by a screw actuated by a friction clutch, the feed being started and stopped by either one of two levers, one at the front of the table and the other at the side of the column, thus placing the machine well under the operator's control. The saw is driven by an endless belt wrapping around idlers in such a way that it preserves its tightness, no matter how far out upon the bracket the saw mandrel may be.

In the railway cut-off saw of the H. B. Smith Machine Co. there is a horizontal table bearing a horizontal cross-head or saddle, which supports in proper bearings the horizontal mandrel of the saw. This cross-head or saddle is attached to a connecting-rod pivoted at its other end to a frame which vibrates about a center at its lower end, this being the center about which a large pulley rotates. From this large pulley a belt rises and passes over a small pulley near the top of the vibrating frame, then horizontally to the saw pulley, back horizontally to a second or upper small pulley on the vibrating frame, and down to the lower or large pulley. A long hand lever enables this vibrating frame to be drawn forward, and with it the saw, giving traverse in the machine. Above the saw bearings are two horizontal guide bars which serve as rests for the stock.

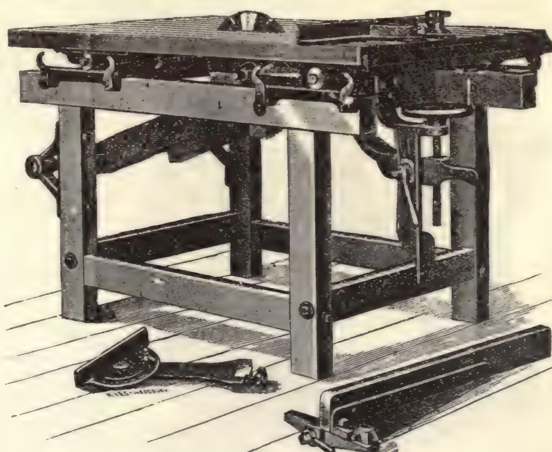


Fig. 6.—Slitting and cut-off saw table.

In the swing cut-off saw shown in Fig. 4, and made by Rowley & Hermance, the frame swings upon the hangers instead of upon the countershaft as in most other machines ; it is adjustable for different heights of ceiling, the saddle holding the arbor having a sliding adjustment of 5 in. ; thus incidentally permitting the saw being entirely used up. The saw is protected by a shield.

In a parallel swing saw machine made by P. Pryibil, Fig. 5, the saw arbor travels in a

horizontal straight line instead of rising and falling in an arc, as in all swing saws, thus enabling a comparatively small saw to be used for wide and thick timber, and permitting the use of a dado-head for grooving, gaining, rebating, tenoning, molding, etc. The moving parts are balanced so that they will stay in any position in which they may be left. The parallelism is given by the main bearings sliding in vertical grooves, and the pendulum being connected at about the center of its length with a link-piece pivoted at about the height of the saw arbor, as shown in the illustration.

The combination slitting and cut-off saw table made by Beach, Brown & Co., and shown in Fig. 6, has a bed mounted upon roller bearings, so as to make it run easily and square with the saw. For dado cutting, grooving, etc., the saw is raised and lowered by a hand wheel and screw, or for ordinary work by a hand lever.

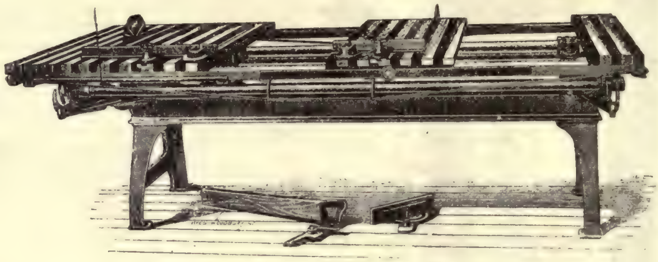


Fig. 7.—Double and single cut-off saw.

The double and single cut-off saw made by Beach, Brown & Co., and shown in Fig. 7, consists of a frame having at the left-hand end a table which is permanently fixed to the carriage, while the right-hand table is free to move along the carriage, carrying with it a movable saw for cutting material of different lengths. The carriage has a truss upon both the front and the back, preventing sagging or springing in the center, and rests upon four flanged differential wheels, having no fixed bearings and serving to lessen friction. The two wheels on the front, and also those on the back, are connected by shafts, so that the carriage moves square with the saws.

In one class of cheap rip-saw benches the machine may be changed from power feed to hand feed by raising the feed works, which are contained in a frame that is pivoted at one end of the machine. This feed is driven by belting, and carries the stuff along by the usual spur wheel having its axis and its plane of rotation parallel with those of the saw.

In one type of miter and bevel sawing machines the table is fixed in height, and has no adjustment at all ; but the saw arbor is raised and lowered in a gibbed frame at such an angle as to keep the belt tension constant ; a central hand wheel in front of the machine accomplishing this adjustment. There is an adjustable bevel fence which works in a planed way to and from the saw, and can be set to different angles. The saw and its arbor can be set to any angle from the vertical plane to 45° by turning a hand wheel at the left of the machine, either while the machine is still or while it is running. This construction and arrangement render it unnecessary to provide more opening around the saw in the table for miter sawing with the saw tilted than with the saw in its vertical position. Having the table level and the saw tipped does away with the necessity of holding the material to the table, as is often desirable where the table is tipped ; furthermore, very long stuff does not come in the way of the floor or of other objects.

A universal sawing machine, Fig. 8, made by R. E. Kidder, has a square box frame, the top of which has vertical adjustment, and is counterbalanced by a weight within. There is a spider rotating on a horizontal axis, and having three arms, each of which has an arbor for a saw or a cutter head, each arbor having two bearings. On one end of each arbor is a saw or cutter, and on the other a clutch which engages with a sliding clutch on the driving shaft, making a continuous shaft when the spider is so rotated as to bring any one of the three arbors in line with the main driving shaft. On the outer end of the main or common shaft is a locking wheel, having three holes and three equidistant projections. Passing through the frame and entering the wheel is a locking pin, on the inner or opposite end of which is attached a fork pivoted to the frame, and the object of which is to disengage the sliding clutch on the driving shaft. The table is raised by a lever in front and clamped in any position.

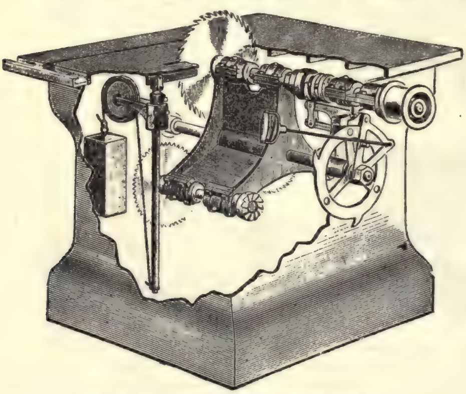


Fig. 8.—Universal sawing machine.

It is of the utmost importance that lumber which is to be matched or jointed should be edged straight, for any irregularity in the edging will be followed by the matcher, and imperfect lumber will be the result. In a power-feed double edger made by the Lane Manu-

facturing Co. the boards are fed through the machine by an endless chain with barbed links, running over spocket wheels which are driven by a friction-feed box having three changes of feed. Heavy rolls in swing frames rest on the top of the board, holding it down to the bed. The barbed chain travels in a planed iron groove which guides it, and a bradded roll at the tail end of the machine causes the board to pass out in line with the chain feed.

There is a large class of circular sawing machines which may be considered under a miscellaneous heading; as, for instance, slab slashers, slat-saws, picket machines, etc. A steam-feed lath machine, made by William E. Hill & Co., has a steam-cylinder feed with a carriage to receive the slab which is to be made into lath. This latter is placed on the carriage, which makes it into lath without its being previously butted. The same machine may be arranged to saw broom-handles from cuts or small round logs, making from two to ten handles at a time, according to the size of the bolt or log. There are two circular saws on horizontal arbors, one in advance of the other, and there is a gang of smaller disks on the vertical rubber, back of the two vertical disks.

A power-feed slab slasher, which differs greatly from the ordinary type of slabbing machines, made by D. S. Abbott, Olean, N. Y., has but one saw, and this is borne on the end of a frame which is pivoted at its lower end, and bears near its upper end a cross-head with projections that engage on the sides of a guide-bar, the outline of which is a circular arc, and which is intended to hold the saw square and true to its work. The table or bed has live rolls which feed the slab. The feed is by friction rolls, and pressure of the foot on a treadle connects the frictions which bring the saw forward and make the cut. When the saw recedes from the cut, and is at or near the back end of its stroke, an arm comes in contact with connections which actuate the friction gear and the live rolls, and they start, carrying the slab forward for the next cut. Pressure again on the foot treadle starts the saw forward, and at the same time releases the frictional contact of the rolls, which stand idle while the saw is making its cut, and start again when the saw swings back to the proper point.

For making square stick slats for wire fences, trunks, etc., it is best to employ a special machine. Such a one has a horizontal carriage, with a track on which there runs a carriage bearing the log or cant to be sawed up; between two parts there is a cross-head or saddle the whole width of the machine, and this bears a horizontal mandrel lying across the line of the track, and a vertical one; the latter having separate adjustment for height and for distance from the parts. The horizontal mandrel bears two saws, which cut their way into the stock to a definite depth, and the horizontal saw upon the vertical axis then makes a cut in a horizontal plane. By adjustment of this last saw the planks may be sawed tapering, with alternate butts and tops, so that the sawing is continually with the grain. This machine saws with the backward movement of the carriage as well as with the forward, thus saving the time otherwise lost in gigging back. The vertical arbor is driven from a vertical drum having the lower end of its shaft in a pot-box on the floor, and its upper end in a timber bearing on the ceiling. In sawing both ways two operators are required, one at each end; they remove the piece that has just been sawed, and adjust the log carriage by a hand wheel until the next log strikes the gauge. When sawing one way, only one operator is needed. The machine automatically reverses itself, the carriage and log start back for another cut; hence the operator must be prompt in adjusting the log over against the gauge. There is a lever by which the carriage may be reversed by hand, if for any reason it is desired to back out of a cut before it is finished.

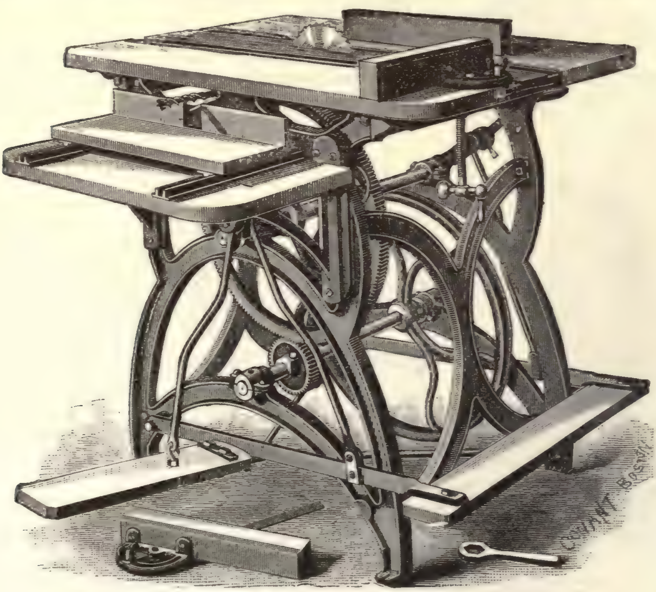


FIG. 9.—Foot-power circular saw.

Foot-power Circular Saws.—The development of a new country would be rendered much more difficult if there were no medium between power-driven machinery and hand tools. In this particular the line of wood-working machinery is especially fortunate in having provision for the large class of small operatives in slightly populated yet growing districts; hand and foot-power machinery for sawing,

boring, etc., being plentiful, and in the main quite well adapted for the work that it is called upon to do.

There may be said to be two classes of foot and hand-power machinery ; those for amateurs and those for workmen. Machines in the first class are usually adapted to do but light work, and several operations on one machine ; the latter are built to stand continued work on stock such as has to go into actual service, and there is seldom the same range of operations.

The application of man power to the circular saw has been of great use to small manufacturers. In this line such a machine as that made by Marston & Co., and shown in Fig. 9, has done good service. There is an iron frame with a wooden top or table ; a treadle in front gives motion to the crank shaft of the machine ; a large spur-wheel drives a small pinion on a lower shaft, which bears a large band-wheel from which a belt extends to a small pulley upon the saw arbor. The large band-wheel serves as a fly-wheel. A crank at the left-hand side of the table, and upon the crank shaft which is driven by the treadle, enables the work of the foot to be supplemented or superseded by hand. Such a machine as this will carry a 7-in. saw, and do cross-cutting and ripping, being supplied with necessary gauges. An extension of the saw arbor enables boring to be done, a separate sliding table for bringing the work up to the bit being added. There is also a side treadle which works independently of the saw treadle, and permits the operator to stand upon the boring side or end of the machine, directly in front of his work.

In another foot-power machine, a scroll-sawing attachment is put on by throwing off the main belt which drives the saw arbor from the fly-wheel, and passing it over the fly-wheel to a small pulley upon a crank shaft, instead of over the fly-wheel to the saw pulley. The lower end of the jig-saw blade is attached to the upper end of a pitman from the crank ; the upper end of the same blade being attached to a wooden spring-beam.

The number of saw filing and gumming machines is legion ; and for circular-saw work they are usually supplemented by a jointer, the teeth in a true circle concentric with the saw arbor. In one saw-mill the jointer is combined with the saw guide, consisting of a block of emery or equivalent abrasive attached to the bracket which bears the guides, and which may be brought up to the teeth, while the saw is running at full speed ; the block being turned as the saw rotates, in order to keep its surface free from scores, which would destroy it and make its work untrue.

An automatic machine for sharpening circular rip-saws of from 8 to 72 in. in diameter, mounts the disk in a frame in which there is a belt-driven emery-wheel, of the proper section to give the desired tooth form ; this cuts its way across and finishes the face of one tooth and the back of another ; then the wheel is brought back to its original position, the disk is moved on the space of one tooth, and the machine continues, automatically, to work its way around the disk, in the same way as a gear-cutting machine does around a blank. There is suitable adjustment to take in disks of various diameters, and the amount of partial rotation after cutting or sharpening each tooth is governed by the position of an arm with regard to a graduated arc. The same principle is adapted to sharpening long, straight blades ; the spacing in this case being in a straight line instead of circular.

Band Saws.—While the band saw was invented about the year 1808, it did not come into use until 1835, since which time there has been a gradual but steady and satisfactory development along various lines of design and work. Its use takes in practically nearly every

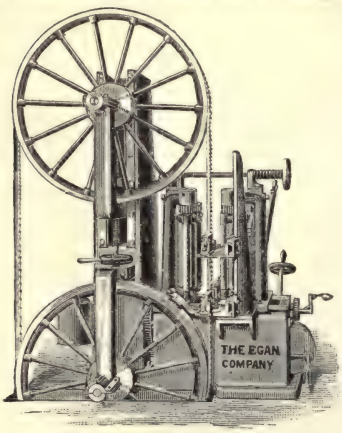


Fig. 10.—Resawing machine.

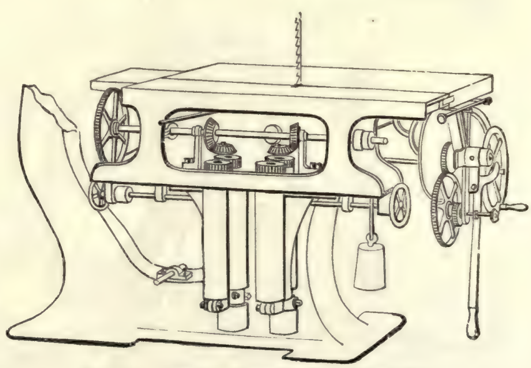


Fig. 11.—Duplex reversible band-saw table.

kind of wood sawing, both curved and straight lines, from very delicate outside fret-work to the heaviest logs ; the latter having band-wheels as large as 96 in. in diameter, carrying 8-in. saws 50 ft. long.

A band resawing machine made by the Egan Co. has the two front feed rolls close to the saw blade, and the tops of the roller brackets are connected, so that the plank may be straight-

ened while sawed. The wheels are of iron with steel spokes, and their mandrels run in self-oiling boxes. The lower wheel is thicker and more solid in the rim than the upper, giving it more momentum, although it may be readily stopped by the brake. Each wheel is supported by an outside bearing each side of the column, giving three bearings each to the upper and the lower shaft. The feed consists of six large geared rolls driven by a graduated feed, so that the speed can be changed at once by turning a hand wheel while the board is being fed through the machine. A ratchet lever connected with the upper guide permits changing the latter to suit the width of board being cut.

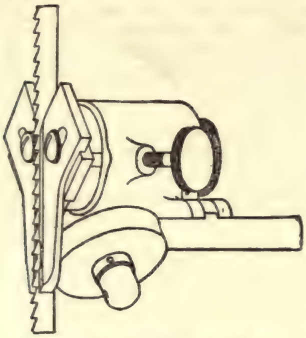


FIG. 12.—Band-saw guide.

Another band resawing machine, Fig. 10, has vertical feed rolls, the front two of which are close to the saw bed, and the system of gearing employed permits the plank being straightened while sawing. The wheels are entirely of iron, and the lower one is thicker and more solid than the upper, giving a certain amount of momentum where it is desired to make the sawing steady, at the same time being within the control of the brake. There are six large feed rolls, heavily geared, and driven by a graduated feed, which permits the speed to be changed instantly, by turning a hand wheel, while the board is being fed through the machine. By a running lever handy to the operator, the upper guide may be changed to suit the width of board. The Egan Co. has made a band resawing machine which will saw a 2½-in. plank into two 1-in. boards at one cut, thus effecting a considerable saving in lumber.

The firm of Marston & Co. makes a hand and foot-power band saw with both hand crank and treadle, and which for outside work will act faster than a hand jig saw. This machine has a capacity of 6 in. in thickness under the top guide, and swings 15 in. between the saw and the frame. The table is rounded for cutting on the bevel. The speed-multiplying rig consists of a large spur wheel on the crank shaft, meshing with a pinion on the lower band wheel; the shaft bearing the latter having a fly-wheel to steady the motion.

For band resaws a very desirable attachment or feature is the duplex reversible table and rolling guides, shown in Fig. 11, the column being broken away in large part. The table is made in two sections, divided upon a line at right angles to the saw teeth. On the front section of the table are mounted the feed works, consisting of four geared rollers having a graduated friction feed, which may be varied at once from slow to fast. These feed rollers have lateral adjustment to suit the thickness to be cut. By loosening a nut in front, upon which the outer section of the table is mounted, it may be turned completely over, its lower side when so reversed forming a clear table for plain band-sawing purposes.

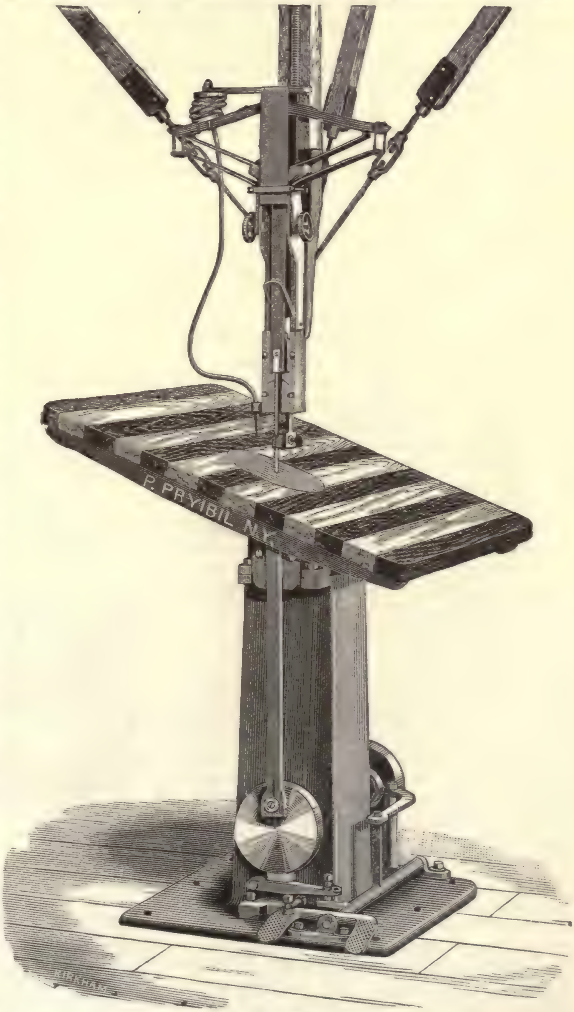


FIG. 14.—Jig saw.

A band-saw guide, Fig. 12, made by Goodell & Waters, has two side guides consisting of metal plates, which are adjustable for thickness of the blade, and a wheel with a back guide, the latter having a grooved or concave periphery, and being set on an angle so that the back of the saw passes diagonally across the wheel periphery, and rotates it. Thus the point of bearing of the wheel against the back of the saw blade is constantly changed, and the saw is prevented grooving the surface of the wheel by continued action in any one place. The saw has a bearing of $1\frac{1}{8}$ in. at the back, and is not liable to twist or turn, even if the side pieces are removed. The wheel runs on a ball bearing.

A desirable feature in band log-mills is the saw deflector, by which, when the direction of the carriage is reversed, the saw blade is automatically drawn back from the surface of the cut, to prevent marking the log, and set back into line before and during the cut. Some band log-mills are made with the engine and the lower band-wheel on a common shaft, and the engine is so arranged that the sawyer has control thereof without leaving his position for running the mill. It is desirable that the position of the band on the wheels be controlled by the operator without leaving his place or stopping the machine, as the collection of dust on the wheels often causes the blade to leave its path, crowding it over against the guides and causing breakage and stripping of the blade. It is also desirable that the tension may be changed at once while the machine is running.

The band saw being so much more delicate and sensitive than the circular, it is well that its feed works be arranged with a friction device in heavy cuts, in order to vary the rate of feed from zero to full speed without stopping the mill.

The increasing use of the band saw has led to the production of filing and setting frames, in most of which there is a general resemblance, except in very minor details. There is a horizontal slab or sole piece, bearing two short vertical standards, upon which are journaled two leather-covered pulleys, having a flange on the lower edge of each. One of these pulley standards is fixed, and the other is adjustable lengthwise of the machine, in order to take in bands of various lengths, to give the proper tension to each while being filed. There are two vises on the same side of the machine, one for filing and the other for setting. The filing vise is of extra length, and has jaws closed by three handles. The setting vise is of cast-iron with beveled steel jaws, and has a small gauge at each end, which can be adjusted for different widths of saws.

Jig Saws.—A jig saw, shown in Fig. 14, and recently made by P. Pryibil, has a lever for depressing its upper slide, which conduces much to speed and convenience in placing and removing the saw. The saw runs in adjustable guides, which can be varied in height according to the thickness of the work, and the strain may be adjusted to suit the saw length. The weight of the strain is balanced by a spiral spring. There is an automatic blower to keep the work free from sawdust. The connecting-rod has adjustable bearings, which are arranged to take up wear endwise in the direction in which it occurs, and not sidewise, as is usual in machines of this class. The machine is started by a friction clutch without belt shifting. Simultaneously with the releasing of the clutch, the machine is stopped by a brake, brought into operation by the same motion which releases the clutch.

In some of the advanced machines for scroll sawing by strained saws, an ingenious feature is that the strain is kept practically constant at all parts of the stroke, by counteracting the loosening flexibility of the spring by an eccentric roller varying the leverage at each point of the stroke.

Scales : see Balance.

SCREW MACHINES. The name screw machine is not properly descriptive of the class of machines to which it is applied. It does not well indicate many purposes for which they have come to be used, and yet it had been too long applied to be readily changed. The name turret lathe is a more generic term, including the screw machines as a variety. (See LATHES.) Designed primarily for making screws, and useful for this purpose whenever screws are not required in sufficient quantities to render entirely automatic machines preferable, screw machines are perhaps chiefly used in making a large variety of pieces from iron or steel bars, and in finishing castings or forgings which may be held in a chuck while subjected to one or more operations. The full extent to which experience has shown that it is profitable to employ them for other purposes than for making screws may be judged from the fact that in the shops of the Brown & Sharpe Manufacturing Co. only one out of every eight is usually employed for this purpose. Three-eighths are ordinarily used in finishing studs, nuts, washers, bushings, pins, handles, etc., from round, square, or hexagonal stock ; while one-

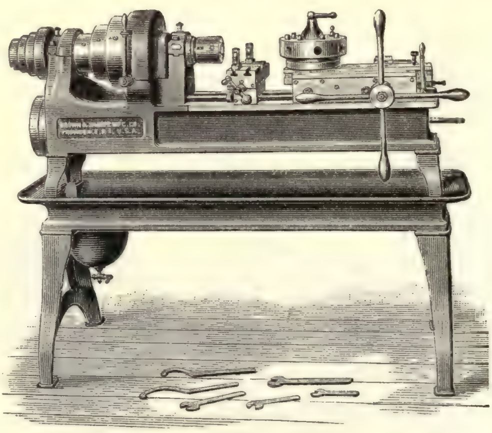


FIG. 1.—Screw machine.

half the machines are generally employed on small wheels, levers, or cams for sewing machines, or on small parts of machine tools.

Fig. 1 represents a new style of screw machine recently introduced by the Brown & Sharpe Manufacturing Co. The head is back-geared, and the change from belt speed to back gears is effected, without stopping the spindle, by a friction clutch which is practically positive in its action and will hold the full belt-power of the machine. The back gears are underneath the spindle-cone and are entirely enclosed. The gears on the cone are also enclosed. The cone has three steps. The turret is fed automatically or by hand, and has eight speeds, as each of the four speeds given by the feed cones may be varied by shifting a lever, so that without changing the belt the tools may be fed fast or slow for each step of the cone. This is a novel feature in screw machines. The turret is $9\frac{1}{2}$ in. in diameter. The movement of the turret-head slide is $9\frac{5}{8}$ in., and the extreme distance between the face-plate and the turret is 32 in. The length that can be drilled, or milled, without moving the turret-head slide-bed is 6 in.

The Niles Screw Machine.—Fig. 2 illustrates a screw machine built by the Niles Tool Works, Hamilton, O. The following is a detailed description: The chuck, *A*, is fast on the hollow arbor of the machine. *B* is a steadying chuck on the rear end of the arbor. *C* is an ordinary lathe carriage, fitted to slide on the bed and be operated by hand wheel, *D*, and a rack pinion. Across this carriage, slides a tool-rest, *E*, operated by a screw, and having two tool-rests, one to the front and one to the rear of the work. This tool-rest, instead of sliding directly in the carriage, as is the case with lathes, is mounted on an intermediate block which fits and slides in the carriage. This intermediate block is moved in and out, a short distance only, by means of a cam lever, *G*. An apron on the front end of the slide carries the lead-screw nut, *H*. When the lever cam is raised it brings the slide outward about half an inch, and the tool-rest, *E*, comes out with it, and at the same time the nut leaves the lead screw. The inward movement of the slide is always to the same point, thus engaging the lead screw and resetting the tool.

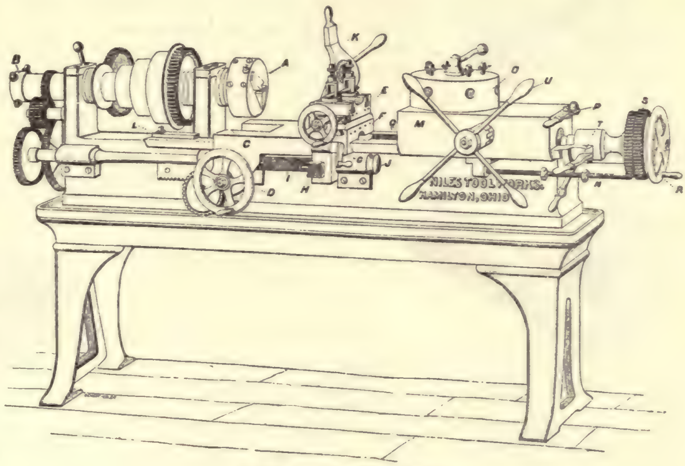


Fig. 2.—Screw machine.

With this machine threads may be cut by adjusting a thread tool in the front tool-post, as in ordinary lathe practice, and at the end of the cut the cam lever serves to quickly withdraw the tool and the lead-screw nut so that the carriage can be run back. The tool-rest is then advanced slightly and the new cut taken. By this means threads are cut without any false motions, and may be cut up close to a shoulder. *I* is the lead screw. This screw does not extend to the head of the machine, but is short and is socketed into a shaft which runs to the head of the machine, and is driven by gearing. The lead screw is thus a plain shaft with a short, removable threaded end. The gearing is never changed. Different lead screws are used for different threads, thus permitting threads to be cut without running back. The lead screws are changed in an instant by removing knob, *J*. The lead-screw nut, *H*, is a sectional nut, double-ended, so that each nut will do for two pitches, by turning it end for end in the apron.

L is an adjustable stop which determines the position of the carriage in cutting off, facing, etc. *K* is an arm pivoted to the rear of the carriage, and carrying three open dies like a bolt-cutter head. *M* is a block sliding on the bed. *N* is a gauge screw attached to this block and provided with two nuts. The stop lever shown in the cut turns up to straddle this screw, and the position of the nuts determines how far each way the block may slide. *O* is the turret fitted to turn on the block. It has six holes in its rim to receive sundry tools. It can be turned to bring any of these tools into action, and is secured by the lock lever, *P*.

The turret slide is moved quickly by hand, by means of the capstan levers, *U*, which by an in-and-out motion also serve to lock the turret at any point. The turret slide is fed in heavy work by the hand wheel, *R*, on its tail screw. This tail screw carries, inside the hand wheel, two gears, *S*, which are driven at different speeds by a back shaft behind the machine. These two gears are loose on the tail screw, and a clutch operated by lever, *T*, locks either one to the screw.

Turret Tools.—The different forms of tools used in the turret on ordinary shop work are illustrated in Figs. 3 to 9.

The end gauge shown in Fig. 4 is simply a hollow shank, A, fitting the turret, and a gauge rod, B, fitting the shank. The shank may be set further in or out of the turret, and the rod may be set further in or out of the shank. The end gauge is so set that when the turret is clear back against its stop the end of the rod B will gauge the proper projections of the bar iron from the chuck of the machine. The center, shown in Fig. 5, explains itself; it is used only in chasing long work in steel. The turner, shown in Fig. 6, consists of hollow shank, A, fitting the turret; a hardened bushing, B, held in its front end by a set-screw; a heavy, mortised bolt, C, in the front lug of the shank; an end-cutting tool, D, shaped like a carpenter's mortising chisel, and clamped by the mortised bolt; a collar-screw E, to hold the tool endwise, and a pair of set-screws, F, to swivel the tool and its bolt. Bushing B is to suit the work in hand. The tool, D, is a piece of square steel, hardened throughout. It is held by its bolt with just the proper clearance on its face. It cuts with its end without any springing, and will on this account stand a very keen angle of cutting edge. It will cut an inch bar away at one trip with a coarse feed. It does not do smooth work, and is, therefore, used only to remove the bulk of the metal, leaving the sizer to follow.

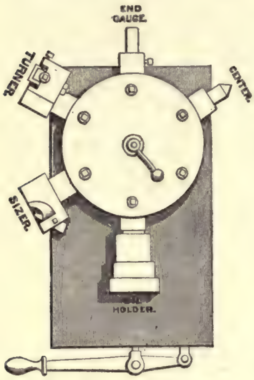


FIG. 3.—Turret tools.

FIG. 4.—End gauge.

FIG. 5.—Center.

The sizer, shown in Fig. 7, consists of a hollow shank, A, fitting the turret and carrying in its front end a hardened bushing, B, and a flat tool, C.

The sizer follows the turner and takes a light water or oil cut, giving size and finish with a coarse feed. Having only light, clean work to do, it holds its size nicely.

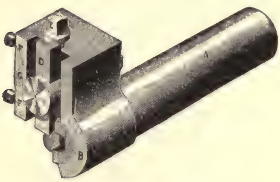


FIG. 6.—Turner.

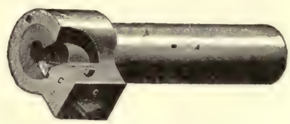


FIG. 7.—Sizer.

The die holder, shown in Figs. 8 and 9, is arranged to automatically stop cutting when the thread is cut far enough. It will cut a full thread cleanly up against a solid shoulder. It consists of a hollow shank, A, fitting the turret; a sleeve, B, fitted to revolve and slide on the front end of the shank, C; a groove, E, bored inside the sleeve; a pin, D, on the shank, fitting freely in the groove, E; a keyway, F, at one point in the groove and leading out each way from it, and a thread die, G, held in the front end of the sleeve. When the turret is run forward the thread die takes hold of the bolt to be cut, but it revolves idly instead of standing still to cut, until the pin, D, comes opposite the keyway, F, when, the turret still being moved forward, the pin enters the back of the keyway. The sleeve now stands still, the die cuts the thread and pulls the turret along by the friction of the pin in the keyway. Finally the turret comes against its front stop and can move forward no further. Consequently the sleeve is drawn forward on its shank, C, and the instant the pin, D, reaches the groove, E, the die and sleeve commence to revolve with the work and cease cutting. The machine is then run backward and the turret moved back a trifle. This

FIG. 8.—Die holder.

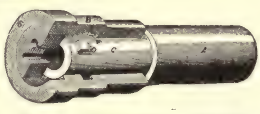


FIG. 9.—Die holder. Section.

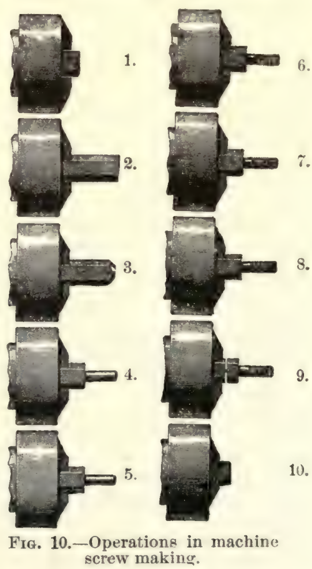


FIG. 10.—Operations in machine screw making.

causes the pin to catch in the front end of the keyway, and the sleeve is again locked. The die then unscrews, and, in so doing, pushes the turret back. A tap holder may be inserted in place of the die, and plug taps may be run to an exact depth without danger.

The following cuts show the operations performed in making a machine screw :

First Operation.—The bar is inserted through the open chuck. *Second Operation.*—The turret being clear back against its stop and revolved to bring present the end gauge, the bar is set against the end gauge and the chuck is tightened. This chucks the bar and leaves the proper length projecting from the chuck. *Third Operation.*—The front tool in the carriage, a beveled side tool, cones the end of the bar so turret tools will start nicely. *Fourth Operation.*—The turret being revolved to present the turner, the bar is reduced at one heavy cut to near the proper size, the turret stop determining the length of the reduced portion. *Fifth Operation.*—The turret being revolved to present the sizer, the body of the bolt is brought to exact size by a light, quick, sliding cut. *Sixth Operation.*—The open die arm being brought down, the bolt is threaded, the left carriage stop indicating the length of the threaded part. *Seventh Operation.*—The turret being revolved to present the die holder, the solid die is run over the bolt, bringing it to exact size with a light cut, and cutting full thread to the exact point desired. *Eighth Operation.*—The front tool in the carriage chamfers off the end thread. *Ninth Operation.*—The back tool of the carriage, a parting tool, cuts off the bolt, the left carriage stop determining the proper length of head. *Tenth Operation.*—The bolt being reversed in chuck, the top of the head is water-cut finished by a front tool in the carriage. This operation is deferred till all the bolts of the lot are ready for it.

Screw Propeller : see Engines, Marine.

Screw-threading Machine : see Nut-tapping Machine.

SCREW THREADS. At a meeting of the American Institute of Mining Engineers, held at Chattanooga in 1885, Major William R. King read a paper on the subject of screw threads, in which he took the ground that the ordinary thread was cut too deep into the iron, and, consequently, the bolt was weakened more than was necessary, and he proposed to remedy the evil by increasing the number of threads per inch, thereby reducing the depth of the thread.

Mr. John L. Gill read a paper before the Franklin Institute, in November, 1887, in which he advocated a thread formed part square and part V. The form of this thread is shown in

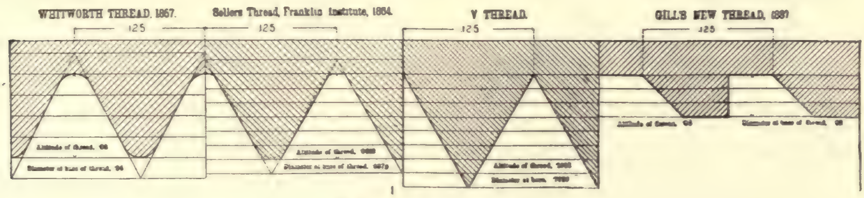


FIG. 1.—Screw threads.

comparison with the Whitworth, the Sellers, and the old V threads, in the cut, Fig. 1. He found that a thread might be made in this way in which the altitude was not dependent upon the pitch of the thread, and that the altitude could be made in proportion to the diameter of the bolt. Making the altitude $\frac{1}{100}$ of an in. high for each $\frac{1}{4}$ of an in. in diameter, would reduce the cross-section of the bolt uniformly 15·35 per cent. on all sizes. On this basis Mr. Gill made a table of sizes from $\frac{1}{2}$ in. to 6 in. in diameter, without reference to the pitch of the threads, and then made a diagram to determine the pitch and the angle of the receding side. He used the same number of threads on the smaller sizes as the Sellers, but on some sizes a different number.

The resisting side of the thread is made at an angle of 90° to the axis, and the receding side at an angle of 45°, the top and bottom of the threads parallel to the axis of the bolt. The flat surface is found by subtracting the altitude from the pitch, and dividing the remainder by two. The iron was of a very good quality, having a breaking strength of over 53,000 lbs. per square inch.

The following table shows the size proposed by Mr. Gill :

A New System of Screw Threads, by John L. Gill, Jr.

1. Diameter of bolt	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.	$1\frac{1}{8}$ in.	$1\frac{1}{4}$ in.	$1\frac{1}{2}$ in.	$1\frac{3}{4}$ in.	2 in.	$2\frac{1}{4}$ in.	$2\frac{1}{2}$ in.	$2\frac{3}{4}$ in.
2. Number of threads per inch	12·	11·	10·	9·	8·	7·	7·	6·	6·	5·	5·	4·	4·
3. Pitch of threads.....	·083	·091	·10	·111	·125	·143	·143	·167	·167	·2	·2	·25	·25
4. Altitude of thread...	·02	·025	·03	·035	·04	·045	·05	·06	·07	·08	·09	·10	·11
5. Width of flat top....	·032	·033	·035	·038	·043	·49	·047	·054	·049	·06	·055	·075	·07
6. Diameter of bolt at base of thread ...	·46	·575	·69	·805	·92	1·035	1·15	1·38	1·61	1·84	2·07	2·30	2·53

A New System of Screw Threads.—Continued.

1. Diameter of bolt	3 in.	3¼ in.	3½ in.	3¾ in.	4 in.	4¼ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5½ in.	5¾ in.	6 in.
2. Number of threads per inch	4·	4·	3·	3·	3·	3·	2½·	2½·	2½·	2½·	2·	2·	2·
3. Pitch of threads.....	·25	·25	·333	·333	·333	·333	·4	·4	·4	·4	·5	·5	·5
4. Altitude of thread...	·12	·13	·14	·15	·16	·17	·18	·19	·20	·21	·23	·23	·24
5. Width of flat top....	·065	·06	·097	·092	·087	·082	·11	·105	·10	·095	·14	·135	·13
6. Diameter of bolt at base of thread ...	2·76	2·99	3·22	3·45	3·68	3·91	4·14	4·37	4·60	4·83	5·06	5·29	5·52

The following table shows a comparison of the V, the Franklin Institute, and the Gill threads for certain sizes :

1. Diameter of bolt..	½ in.	¾ in.	1 in.	1½ in.	2 in.
2. Number of threads per inch, V and Franklin Institute threads	13·	10·	8·	6·	4½·
3. Number of threads per inch, Gill thread	12·	10·	8·	6·	5
4. Altitude of  V thread..........................	·0666	·0866	·1082	·1444	·1924
5. Altitude of  Franklin Institute thread ...	·0500	·0649	·0812	·1083	·1443
6. Altitude of  Gill thread...............	·02	·03	·04	·06	·08
7. Width of flat top of Franklin Institute thread.............. ...	·0096	·0125	·0156	·0210	·0280
8. Width of flat top of Gill thread	·032	·035	·043	·054	·06
9. Diameter of bolt, full section..................................	·5	·75	1·	1·50	2·
10. Diameter of bolt at base of V thread	·3668	·5767	·7836	1·2112	1·6152
11. Diameter of bolt at base of Franklin Institute thread..........	·3993	·6201	·8376	1·2834	1·7114
12. Diameter of bolt at base of Gill thread.........................	·46	·69	·92	1·38	1·84
13. Area of cross-section, original size..............................	·1963	·4418	·78539	1·7671	3·1416
14. Area of cross-section at base of V thread......	·1056	·2612	·4822	1·152	2·048
15. Area of cross-section at base of Franklin Institute thread.....	·1262	·3019	·5510	1·2956	2·3003
16. Area of cross-section at base of Gill thread..................	·1662	·3739	·66476	1·4957	2·659
17. Per cent. reduction of cross-section for V thread..............	58·19	40·78	38·63	34·81	34·65
18. Per cent. reduction of cross-section for Franklin Institute thread..	35·71	31·66	29·84	26·71	26·71
19. Per cent. reduction of cross-section for Gill thread......... ..	15·35	15·36	15·35	15·36	15·36
20. Franklin Institute bolt, per cent. stronger than V....	19·50	15·59	14·27	12·41	12·40
21. Gill bolt, per cent. stronger than Franklin Institute..........	31·69	23·84	20·64	15·44	15·50
22. Gill bolt, per cent. stronger than V............................	57·38	42.76	37·86	29·77	29·83

Mr. Gill made some tests to determine the strength of bolts made with his thread, as compared with bolts of the same iron with the Sellers' thread, with an elastic limit of from 63 to 68 per cent. of the breaking load. It was very ductile, the elongations averaging over 21 per cent. in 10 in. The nuts were from common stock and were excellent, as not one of them showed any tendency to give way in the thread. Six specimens of each size, ½-in., ¾-in., and 1-in., all 20 in. long, were tested to determine the quality of the iron. Six specimens of bolts of each size, ½-in., ¾-in., and 1-in., having the Sellers thread, and six specimens of each size, ½-in., ¾-in., and 1-in., having the new thread, were also tested.

An abstract of the results is shown forth in the following table :

Diameter of bolts..	½ in.	¾ in.	1 in.
Area of cross-section at base of thread..............................	·1662	·3739	·66476
Breaking load of specimens..	10,796	23.600	42.142
Breaking load of iron per square inch..............	54,998	53,418	53,657
Elastic limit of iron	6,946	12,260	26,829
Elastic limit per cent. of breaking load..................................	64·33 p. c.	68·89 p. c.	63·66 p. c.
Gill thread reduces cross-section of bolt by calculation in table	15·35 p. c.	15·36 p. c.	15·35 p. c.
By actual test, by breaking load..................	11·45 p. c.	13·26 p. c.	11·95 p. c.
Sellers thread reduces cross-section of bolt by calculation in table	35·71 p. c.	31·66 p. c.	29·84 p. c.
By actual test, by breaking load	30·16 p. c.	29·04 p. c.	30·21 p. c.
Strength of Gill bolt by calculation in pounds with iron of above strength	9,140	19,973	35,669
By actual test...	9,560	20,471	38,124
Strength of Sellers bolt by calculation in pounds with iron of above strength ..	6,940	16.126	29,595
By actual test..	7,540	16,747	29,411
Gill bolt stronger than Sellers—per cent. by calculation in table......	31·69 p. c.	23·84 p. c.	20·63 p. c.
Per cent. stronger by actual test, by breaking load	26·79 p. c.	22·24 p. c.	29·69 p. c.

Experiments were made to determine how thin a nut would have to be before the thread would strip. On a 1-in. bolt having the Sellers thread, a nut the thickness of $\frac{4}{10}$ of the diameter was found as likely to strip the thread on the bolt as to break the bolt. The thread will never strip in the nut if of a good quality, as the circumference at the bottom of the thread on the bolt is much less than the circumference of the thread at the base inside of the nut. On the Gill bolt a nut was required to be as thick as $\frac{9}{10}$ of the diameter. At that thickness of the nut the bolt both broke and stripped, while at ·95 the bolt broke, and at ·85 the thread stripped; so if the nuts are made of the same thickness as the diameter of the bolt, there will be a margin of 11 per cent. in favor of the bolt breaking instead of stripping.

Scutching: see Rope-making Machine.

SEEDERS AND DRILLS. All classes of seeders have been improved and simplified to such an extent as to come into general use, so that hand sowing has been quite superseded. The Moline broadcast seeder (Fig. 1) is made by the Deere & Mansur Co., for use with or with-

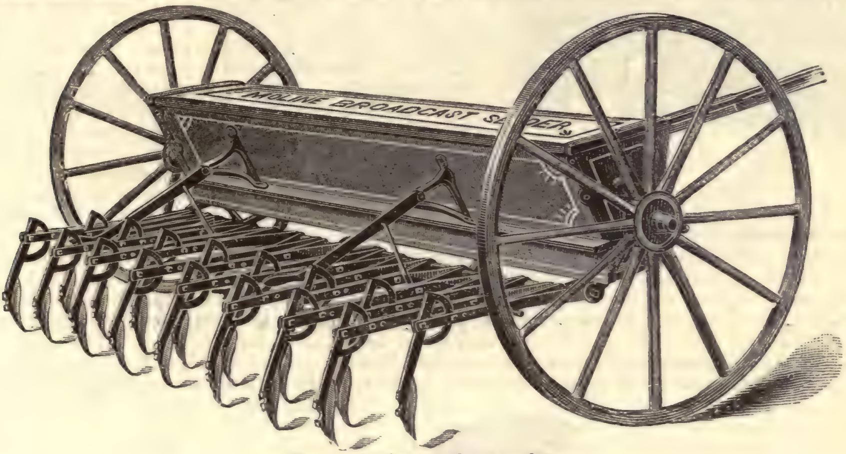


Fig. 1.—Moline broadcast seeder.

out the harrowing attachment, which is made detachable, and with pivoted or "slip" teeth, held to work by springs capable of yielding to the resistance of immovable obstacles, so that the teeth may rise and draw over them without breakage. This seeder has a series of seed-vents in the bottom of the hopper, adjustable to suit the kind of seed sown, and over each vent a stirring-wheel, rotated by the main axle, to prevent clogging and insure a uniform flow of seed. The adjustability of the vents is shown in Fig. 2, an arrangement which adapts the machine to sowing the small seeds of grasses as well as grain. The low delivery admits of use in windy weather.

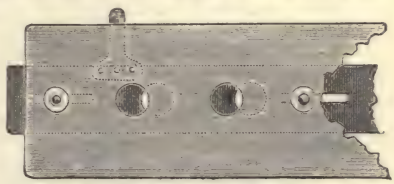


Fig. 2.—Seeder.

In the so-called Hoosier grain-drill there is a ratchet device in the hub of each ground-wheel, rendering both wheels driving wheels; and either will drive the feed or back out of gear. The adjustable fluted-roll force-feed may be adjusted respectively for sowing smaller and larger quantities. Beneath the hopper of the machine, within the feed-cups, is a series of these fluted feed-rolls. In each cup is a scalloped ring which revolves with the fluted roll, fitting into its grooves. The rolls are all fastened to the square feed-rod shown, and are movable lengthwise with it by means of a suitable hand lever, the movement of which to right or left causes more or less of the face of the feed-rolls to pass into or out of the scalloped rings, and to be thereby removed from or brought into contact with the grain. Within the feed-cup and on the opposite side from the scalloped ring, attached to the feed-rod close against the rolls, is a hub or follower cutting off the flow of seed from that portion of the cup not exposed to the feed-roll when the feed is set to sow anything less than full capacity. The graduated scale seen on the back of the hopper is provided with an indicator secured to the feed-rod and affected by its movements, showing on the indicator-plate the quantity of wheat, oats, barley, or flax-seed the machine is set to sow at any given time, and the hand lever for regulating quantity is held by a thumb nut at any desired point. The "force" feature, it will be seen, is constant, whatever the quantity or character of seed delivered. When the ground-hoes are raised the feed-rolls are thrown out of gear by a suitable shifter, and again put in motion by letting the hoes down. The sowing of fertilizers is attended with difficulty. Combined grain and fertilizer drills are made to sow grain or grass seed and fertilizer simultaneously, or either alone. On account of the weight of load carried, the wheels have 3-in. tires to support them on soft ground. A distinctive improvement is the fertilizer force-feed, which delivers the fertilizer into the top of a large rubber spout, forming a junction below with a branch spout from the grain force-feed, where the grain and fertilizer unite to pass through

a hollow hoe-shank to the ground. The fertilizer feed is a series of nicely-fitted circular plates rotating horizontally, one for each hoe, forming a considerable part of the hopper-bottom. As the plates revolve, the contents of the hopper resting on them are carried to oblique gates at the rear, and a stream of the fertilizer is forcibly cut off and discharged. The opening or vent is enlarged or diminished in all the gates simultaneously. When the machine stops, the feed ceases to rotate, and the flow of the fertilizer cannot continue, as the vent does not open downwards—thus the delivery is free when in motion, without waste when stopping, and is proportioned exactly to the speed of the team. This fertilizer feed may be thrown in and out of gear independently of the grain-feed and without disturbing the adjustment for quantity, to skip strips of rich ground. It is now quite common to combine the function of seeding with any style of the rotary or "cutaway" harrows, as illustrated, for example, in Clark's machine, Fig. 3, the seed being dropped just in front of the gang. Most soils that have been plowed within a year can be seeded in one operation, in this way, by placing the seed in a division of one-half of the seed box, driving the harrow a half lap, and completing the work the second time around with the other gang. By thus operating, a good seed-bed is made and the seeds planted therein half the width of the machine with each round.

Fig. 3.—Clark's seed-harrow.

Land Roller.—By rolling the soil after sowing, germination is hastened and a level surface is provided, which facilitates harvesting. Fig. 4 is a roller made by the Van Brunt & Davis Co., Horicon, Wis. It cramps and turns like a wagon. Its rolls are made small, to concentrate weight and compress the soil more compactly in proportion to weight. In each pair the front roll is arranged to press comparatively lightly and prepare the surface of the ground for heavier pressure from the second roll, leaving it more even than single rolls. The rolls are hollow, to save freight, and to be ballasted to suit the land. The tongue is hinged, and the horses pull directly by the roll frames.

The Deere Corn Planter, manufactured by the Deere & Mansur Co., Fig. 5, can be

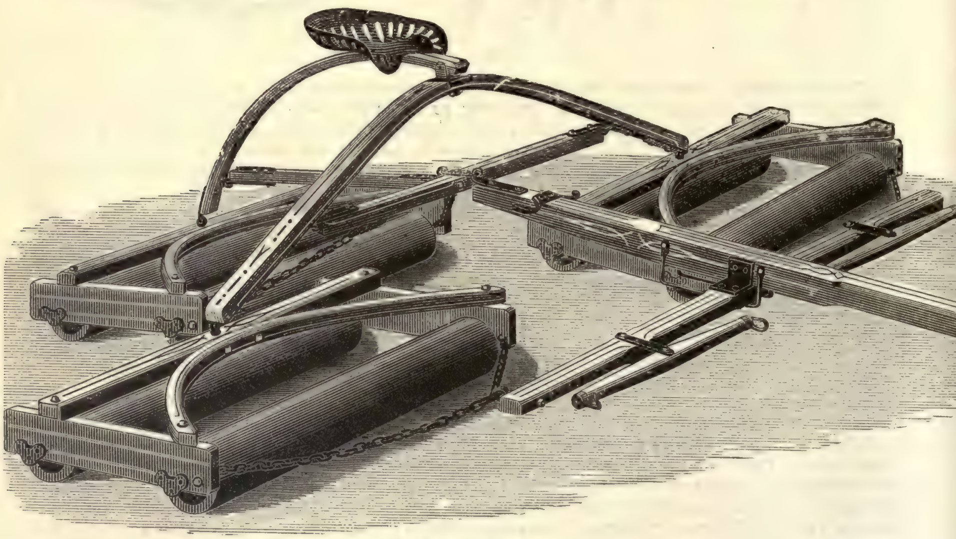


Fig. 4.—Land roller.

made to sow the corn in drills formed by the runners seen in cut, or to drop with considerable accuracy a determinate number of kernels in two hills transversely opposite, by means of a rotary feed beneath the hopper carrying the seed, controlled either by the hand lever, or a check-rower, the latter operated by a light wire cable armed with spurs at distances equal to the distances which it is decided should separate hill from hill. The cable is anchored at either side of the cornfield in order to hold it stationary as the machine advances along its length, so that each collision of the check-rower device with one of the spurs of the cable moves the two droppers simultaneously by a connecting shaft and pinions. The feed is low and the seed dropped instantly, leaving the hills of corn in accurate line both ways. The transverse rows of hills are kept straight by shifting the anchor at the side of the field always in a straight line. The wire can be thrown out of the check-rower on arriving at the end of the row, so as not to interfere with turning the machine. In Fig. 6 the wire is seen wound on a reel, convenient for placing in position for work. The face of the

wheels is a broad concave, tending to cover and press the dirt upon the seed in the drill left by the press runners. The rear of the shank of the runners is of glass, that the process of dropping may be observed by the driver. A slide drop was first used in this class of planter,

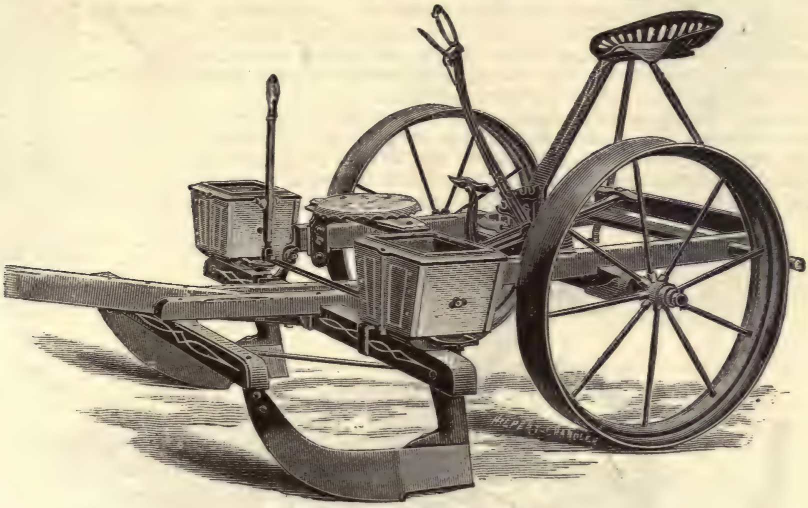


FIG. 5.—Deere's corn planter.

but the rotary drop is found preferable. The check-rower mechanism operates as follows: Spurs or buttons on the wire engage a lever and carry its end to a point where the inclination of the lever sheds the spur, which passes readily in and out of the check-rower on grooved rollers. The movement of the lever draws a small crank over forward far enough to operate the rotary feed to which the shaft of the crank is suitably attached. The heel of the

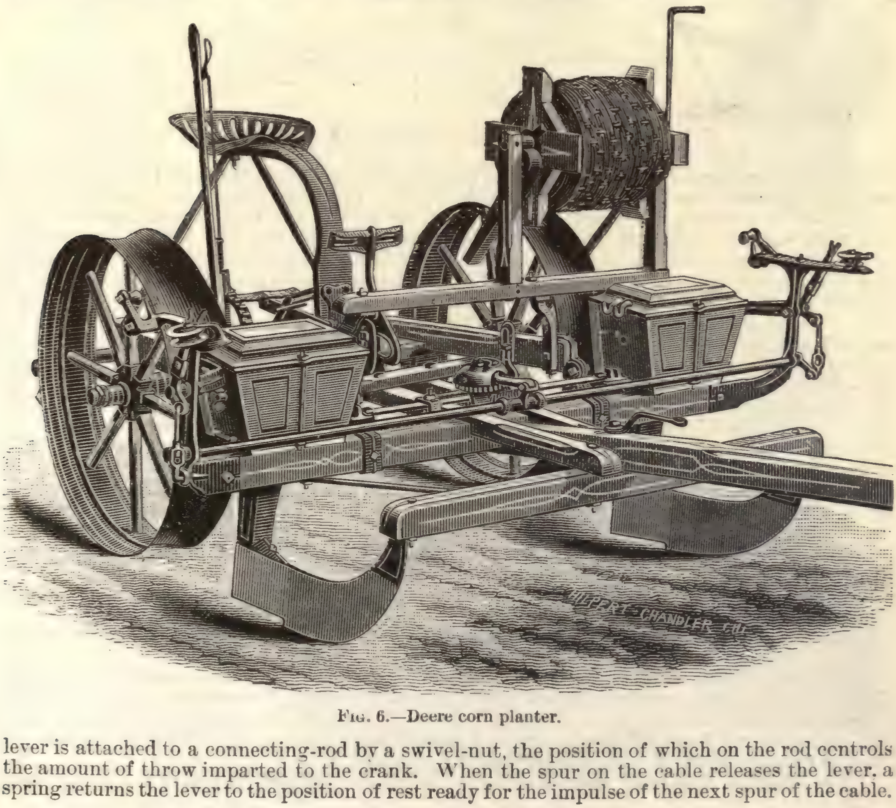


FIG. 6.—Deere corn planter.

lever is attached to a connecting-rod by a swivel-nut, the position of which on the rod controls the amount of throw imparted to the crank. When the spur on the cable releases the lever, a spring returns the lever to the position of rest ready for the impulse of the next spur of the cable.

In another form of the check-rower device the spurs of the wire engage a vertical lever and draw it down backward, escaping to the rear as soon as it assumes a position nearly horizontal, when its return spring causes it to fly back upright, ready for the next impulse, without permitting the wire to escape from its fork.

An upright check-rower anchor by the Barlow Co., Quincy, Ill., is shown in Fig. 7, which unlocks the wire automatically as the corn-planter approaches it, paying out sufficient surplus wire to admit of planting to the extreme end of the row. This surplus is recovered by the operator, who pulls the wire taut again when resetting the anchor behind the corn-planter before starting on his return trip across the field.

Procter's three-row corn planter checks the corn rows both ways in straight lines by mechanism contained within itself, without the use of a spurred wire, at the same time stamping an impression in the dirt at intervals of two hills as a visible evidence to the driver that he is planting his cross-rows straight. To prevent momentary variations in the speed of either of the two animals which draw it, the hitch may play from side to side, while the preserva-

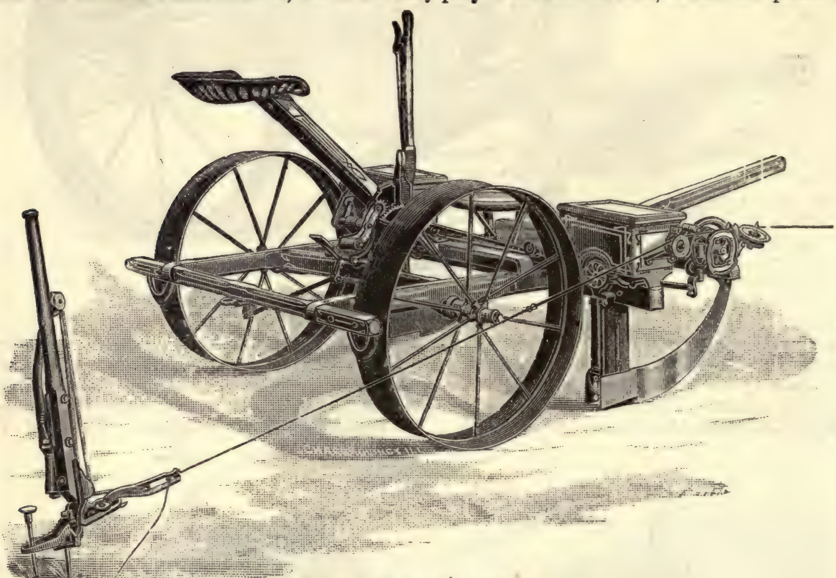


Fig. 7.—Barlow corn planter.

tion of the direction of travel in a general straight line maintains the travel of the machine so as to insure virtually straight rows. Across the machine, hinged to the axle-stock, is a rock-shaft actuating the three seed-slides of the seed-boxes, and provided with a striking plate on the ends next to the tappet-wheels, which are secured to the carrier-wheel spokes, and upon which the checking tappets strike in succession, delivering the corn through the tubes to the hill. The stampers on the two tappet-wheels are arranged to impress the ground simultaneously with the drop of the seed, leaving a visible mark close beside each hill. The stamper and the drop-tube may be swung forward or back in unison, to correct any slight irregularity without stopping. This machine covers the hill with drag-hoes in pairs. The Weir cotton or corn drill requires change of seed-box for cotton seed or corn. The shovel for opening the furrow and the two covering shovels are arranged to trip and draw over obstructions to avoid breakage, and may be given any desired resistance, according to the nature of the ground. The shanks of the covering-shovels are round, so that the shovels may be set at any angle to throw the dirt over the drill, more or less. The seed is taken from the box by a picker-wheel revolved through the medium of chain gear driven by two cranks upon the ends of a shaft traversing the box and carrying an agitator-wheel within it to prevent clogging. The cranks are driven by two connecting-rods extending to cranks on the drive-wheel axle. By setting the cranks at a relative angle of 90°, with the rods parallel, the power is properly transmitted to the picker-wheel. The feed is thrown out of gear by the long rod under the frame, attached in front to a clutch on the main shaft. In the Moline beet seeder, the runner drills are followed by spring press-wheels. The rider's weight is partly sustained by a rear caster, which also carries a hinged marker.

Separator : see Cotton-spinning Machines, Ore-dressing Machinery, and Threshing Machines.

SEPARATORS, STEAM, are used to separate and remove the water entrained or mechanically suspended in a current of steam flowing through a pipe. The names "eliminator" and "extractor" are also applied to the same apparatus, and also to contrivances for removing oil, grease, or grit from exhaust steam, as it passes from an engine to a condenser, or to a system of pipes in which it is utilized for heating purposes.

The Stratton Separator, shown in Fig. 1, is based on the principle that if a rotative mo-

tion is imparted to the steam the liquid particles it may contain, being heavier than the steam, acquire centrifugal force and are projected to the outside of the current. It consists of a vertical cylinder with an internal central pipe, extending from the top downward about half the height of the apparatus, leaving an annular space between the two. A nozzle for the admission of the steam is on one side, the outlet being on the opposite side or on top. The lower part of the apparatus is enlarged to form a receiver of considerable capacity, thus providing for a sudden influx of water from the boiler. A suitable opening is tapped at the bottom of the apparatus for a drip connection, and a glass water gauge shows the level of the water in the separator. The current of steam on entering is deflected by a curved partition and thrown tangentially to the annular space at the side near to top of the apparatus. It is thus whirled around with all the velocity of influx, producing the centrifugal action which throws the particles of water against the outer cylinder. These adhere to the surface, so that the water runs down continuously in a thin sheet around the outer shell into the receptacle below, while the steam, following a spiral course to the bottom of the internal pipe, abruptly enters it, and passes upwards and out of the separator.

FIG. 1.—Stratton separator.

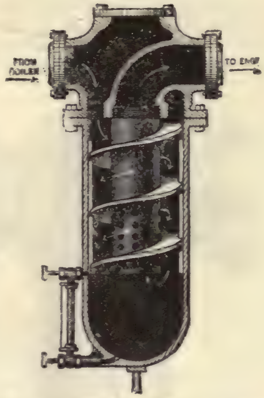


FIG. 2.—Centrifugal separator.

Robertson's Centrifugal Separator is shown in Fig. 2. In this separator the steam is compelled to take a whirling motion by the spiral passages around the central tube.

Hine's Eliminator.—The Hine eliminator is shown in section in Figs. 3 and 4. The interior surfaces have deep, sharp corrugations throughout, extending transversely to the current, by which the steam is thoroughly broken up upon entering. In Fig. 3 a sharply corrugated vertical diaphragm is interposed between the inlet and outlet side. By the force of the incoming current the steam is driven downward against this diaphragm, and by impinging the transverse corrugated surfaces in the body, the initial separation takes place before the turning of the steam into the outlet side.

At the lower end of this vertical diaphragm two convex disks, *B B*, are placed, having a narrow orifice at the bottom, through which the particles separated are carried into the chamber below, out of and away from the action of the steam current, and from thence out at drip valve, *A*. By the interposition, also, of an inward extending pipe at the point of outlet, the steam current is also diverted.

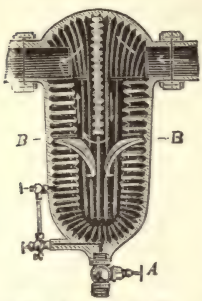


FIG. 3.—Hine's eliminator.

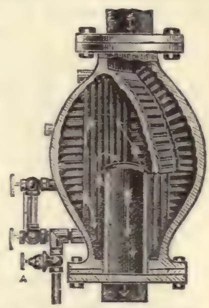


FIG. 4.—Hine's eliminator.

In Fig. 4 is shown, at the side on one end, a corrugated deflecting partition which extends half the length of the body, forming the inlet. At the opposite end a vertical pipe cast with a flange and standing out from the body forms the outlet. The steam in passing through the deflecting partition obtains centrifugal action, and by contact with the inner corrugated surfaces is broken up, and the water, oil, grease, or other particles eliminated readily flow down the vertical corrugations and out, while the steam, diverted from its direct current, passes away from the body and out through the vertical pipe to point of delivery.

Kieley's Multitubular Oil Separator is shown in Fig. 5. Both the inner and outer sides of the tubes are covered with wire coils, increasing the effective area for retaining the oil.

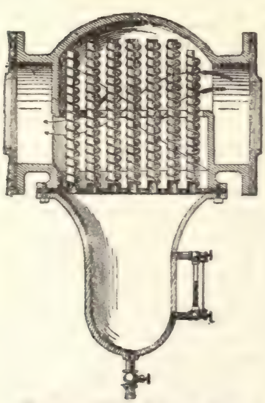


FIG. 5.—Kieley's separator.

The Curtis Combined Separator and Trap is shown in Fig. 6. The steam in its passage through the separator is sharply deflected downward,

FIG. 6.—Curtis separator and trap.

and then as sharply deflected upward. The particles of water by their momentum continue onward instead of turning with the steam, and are projected against the inclined faces of the deflector, and gradually falling, as they lose their momentum, are gathered in a stream against the back side of the separator, and flow downward to the base. The water in the base is removed by a balanced float-trap.

Stuart's Oil, Grease, and Dirt Extractor is shown in Fig. 7. It has for its object the removal from the exhaust steam (before it reaches either the condenser, pumps, or boilers) of all oil, grease, or grit, by the action of surface plates placed in the exhaust pipe, and also by draining the valve chests and steam casings into the oil cylinder, by suitable connections.

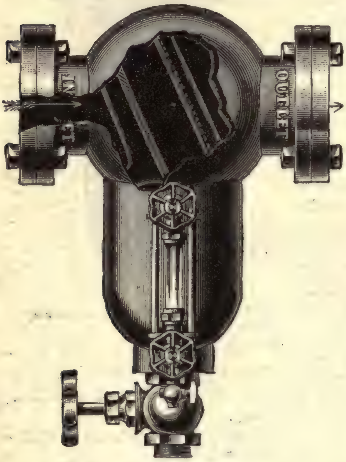


Fig. 7.—Stuart's extractor.

Tests of Steam Separators.—A test of the efficiency of steam separators of six different kinds was made in 1891, by Prof. R. C. Carpenter, at Cornell University. Each separator was subjected to the same conditions. Steam was furnished by a 60-horse-power boiler. From the separator it was led to a 20-horse-power engine, which was belted direct to a Buffalo blower. Thus a constant load was placed upon the engine, insuring a uniform velocity of steam through the system. The quality of the steam before entering and leaving the separator was determined by means of a calorimeter. In order to obtain a wider range of quality than that furnished by the boiler, a vertical section of the steam pipe was enclosed with a drum or cylinder. This drum had several openings along the side to permit water being introduced at various heights, and an outlet was arranged at the bottom, thus maintaining a good circulation. The steam was thus partially condensed and charged with water. The qualities of the steam before and after passing the separator, which have the best result, and the efficiency of separation, which is the ratio of per cent. of water removed to per cent. of water in the entering steam, are given in the following table:

Quality before.	Quality after.	Efficiency, per cent.
98·0	98·0	0·
97·8	99·1	59·1
96·1	98·4	59·0
95·3	98·2	61·7
90·1	98·0	80·0
80.4	98·1	90·3
79·5	98·2	91·2
63·0	98·0	94·6
58·0	98·0	95·2
54·4	98·1	95·8
54·3	97·9	95·4
51·9	98·4	94·6

Each separator reached a maximum efficiency at about 35 per cent. of moisture. No marked decrease in pressure was shown by any of the separators, the most being 1·7 to ·6 lbs.

The investigation shows that although changed direction, reduced velocity, and perhaps centrifugal force are necessary for good separation, still some means must be provided to lead the water out of the current of the steam. If such provision is not made, momentary separation may occur, but before the water can drop or run from any surfaces in the direct current, it will be again taken up by the rapidly moving steam which continually surrounds it. The high efficiency obtained was probably largely due to means having been provided for leading away the water after separation.

Settler: see Mills, Silver.

SEWING MACHINES. I. Machines for Domestic Use.—*Lock-stitch Machines. The Wheeler & Wilson Machines.*—In the latest forms of machines of this manufacture the principal improvements consist in the extension of the rotary mode of motion to every part of the mechanism which does not require a different movement; in devices for interlocking the threads, and for securing uniform feed and exact tension, and also for producing ornamental stitchings. The newest family machine (No. 9) is represented in Fig. 1. Motion is transmitted from the upper to the lower shaft by a crank and sliding connection; a pin at the lower end of the latter, working in a slotted crank arm, gives the necessary variable motion to the lower revolving shaft, and consequently to the rotating hook, thus affording sufficient time for the take-up to draw up the loop of upper thread between the casting-off of the loop from the hook and the descent of the needle to form the next stitch. Fig. 2 shows the bobbin of under thread in its case, and the tension spring on the latter. The amount of tension may be regulated when necessary by turning the screw, *R*, but when once properly set the tension is substantially automatic, adapting itself to the different sizes of thread. Fig. 3 shows the relations of the bobbin and case to the holder and the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BRIDGEPORT, CONN. U.S.A.
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rotating hook. These parts are brought into proper position by closing the drop, *a*, which is firmly held upright by the catch-spring, *b*. Fig. 4 shows the face-plate of the machine and the passage of the upper thread through the thread check, tension pulley, thread controller, and take-up, which last is provided with a roller to reduce friction on the thread, and to facilitate sewing with threads of poor quality.

In the "variety-stitch machine" the loop-taker (or rotary hook) is set with its axis of rotation at right angles to that of the main lower shaft of the machine ; the needle-bar is carried in a swinging gate connected with a segment lever, which is actuated by a cam on

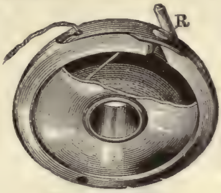


FIG 2.—Bobbin.

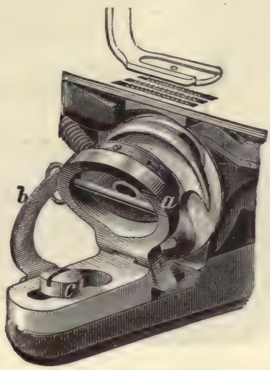


FIG. 3.—Bobbin case.

FIG. 4.—Face plate.

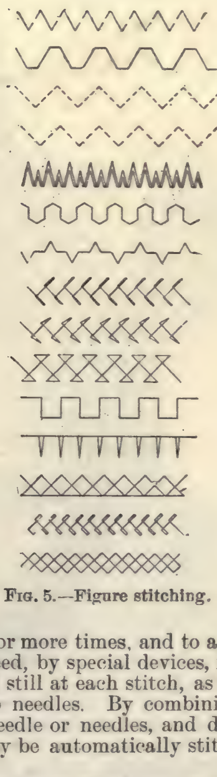


FIG. 5.—Figure stitching.

the upper shaft, and causes the needle to vibrate laterally one or more times, and to a greater or less distance during each revolution of the shaft, and the feed, by special devices, is made to move forward or backward, to the right or left, or to stand still at each stitch, as may be required. The machine may be used with either one or two needles. By combining different numbers and lengths of transverse vibrations of the needle or needles, and different movements of the feed, an almost endless variety of figures may be automatically stitched, a few of which are represented in Fig. 5.

The Domestic Machine, Fig. 6, has an improved feed mechanism. The lever, *A*, imparts horizontal vibrating motion to the feed-bar, and receives its motion through the stirrup, *B*, an eccentric on the shaft and the stitch-regulating mechanism, the lower end of which latter is seen in the form of a groove at *C*. A projection from *B* plays vertically in this channel-way,

which is so pivoted that an arm from it extending up through the bed, and connected with a scale of distances, may be moved in either direction, thus giving any desired throw to the feed, and in either direction. The feed-dog is regulated in height by the nut, *D*. *E* is a thumb-nut to secure the arm wherever located. *F* is a thumb-nut to fasten the stop, which secures uniformity of stitch, whether feeding forward or backward.

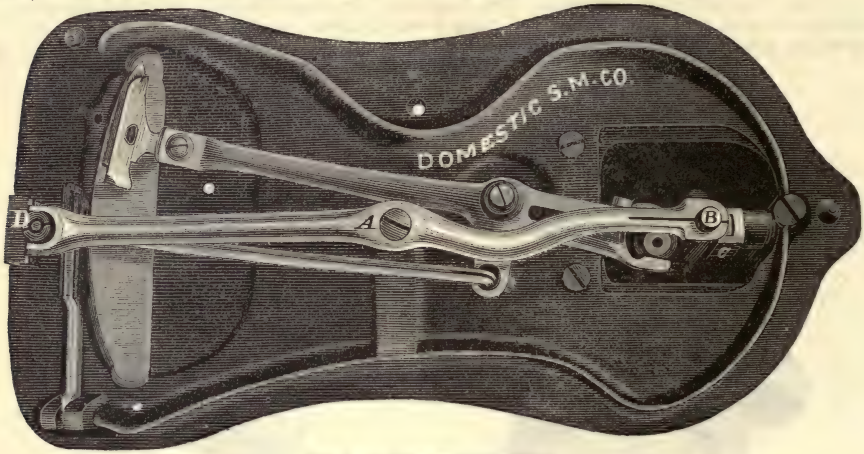


FIG. 6.—"Domestic" machine.

The Willcox & Gibbs Machine in its latest form is represented in Fig. 7. As the parts are all named on the engraving, detailed reference is unnecessary. It has novel means for regulating the tension and the pressure on the material, and for altering the length of stitch.

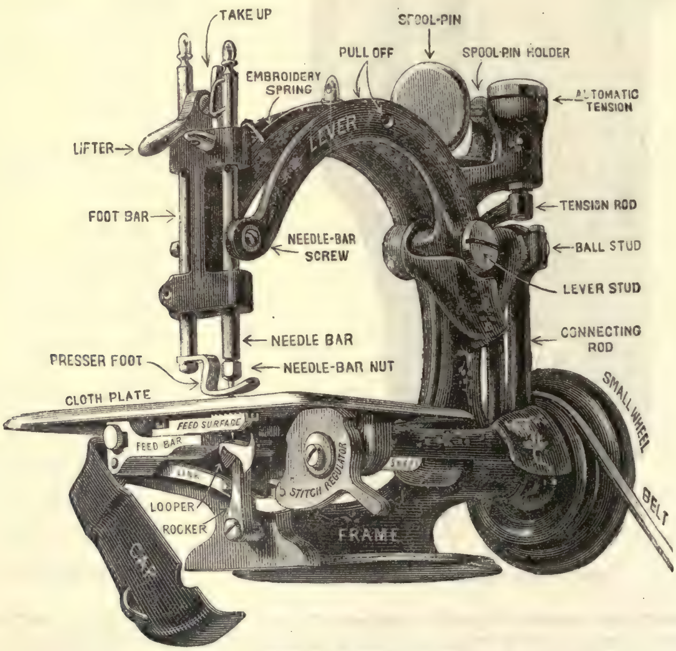


FIG. 7.—Willcox & Gibbs machine.

Combined Lock and Chain-stitch Machines.—A novel machine of this class, illustrated in Fig. 8, is made by the Domestic Sewing Machine Co. A chain stitch looper is substituted for the shuttle, and is attached to the carrier. The second loop is carried around the hook and upon the arm of the looper device, where it is slightly retarded by the tension spring. As it passes off the arm it forms the stitch.

Chain-stitch Machines.—The mechanism of a new machine of this class made by the Singer Co. is shown in Fig. 9. The stitch is formed from a single thread which is inter-

woven into a chain upon the under surface of the goods. and the tension is capable of adjustment so that the thread will be drawn closely to the fabric, forming a tight and flat seam, or left in an elastic chain suitable for knit goods. A beautiful ornamental stitch, resembling braid, is produced by the use of coarse silk or thread.

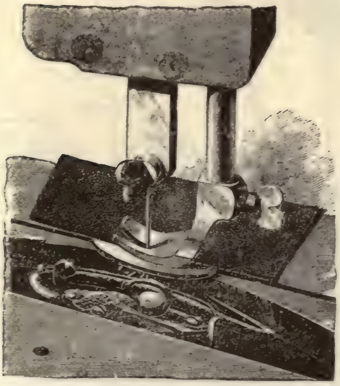


FIG. 8.—Lock and chain stitch machine.

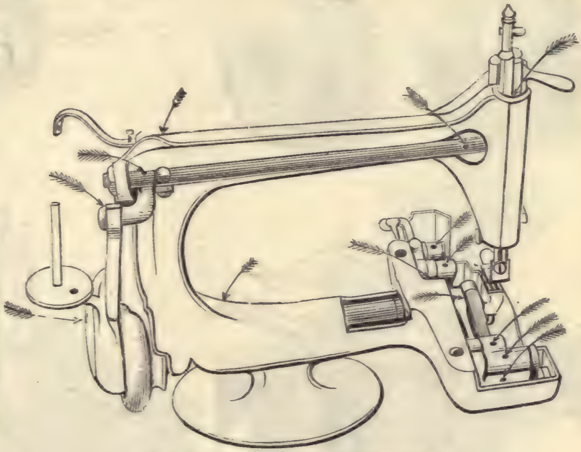


FIG. 9.—Singer chain-stitch machine.

II. MACHINES FOR MANUFACTURING PURPOSES AND HEAVY WORK.—*The Wheeler & Wilson No.* 12 *Machine*, Fig. 10.—In this machine the moving power is applied to the upper revolving shaft, which communicates a uniform rotary motion to the lower main shaft by means of two connections and double quartering cranks. The loop-taker (which takes the place of the ordinary rotating hook, such as is used in the No. 9 machine) passes through the

FIG. 10.—Wheeler & Wilson heavy work machine.

loop of upper thread. It moves in a circular guide with a motion alternately accelerated and retarded. It is rotated by means of a driver attached to a short shaft, the axis of which is eccentric to that of the main lower shaft, and which in consequence of the eccentricity receives a variable motion from the motive lower shaft by a link connection, as shown in

the figure. The axis of the driver is also eccentric to that of the loop-taker, so that, by reason of this eccentricity, the necessary openings for the free passage of thread between the

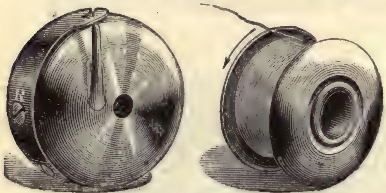


FIG. 11.—Bobbin.

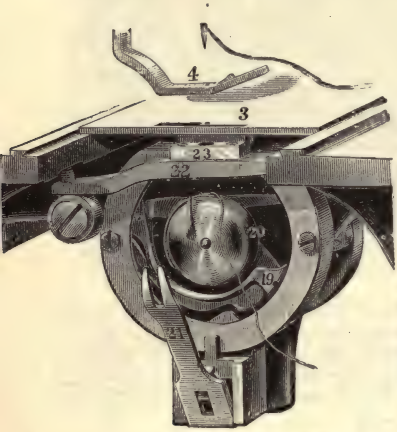


FIG. 12.—Bobbin case.

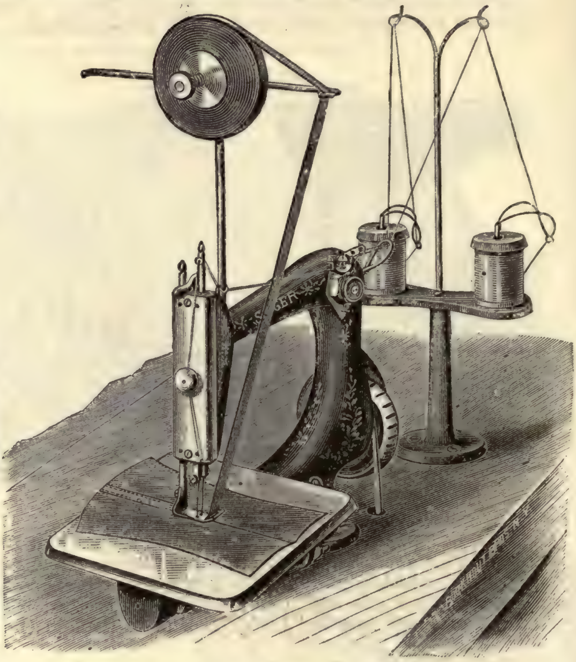


FIG. 13.—Two-needle machine.

driver and the loop-taker are alternately formed at either end of the driver. By this arrangement the loop of upper thread is carried around the bobbin of lower thread without meeting with any resistance. Fig. 11 shows the large bobbin of this machine, and its case, with adjustable tension spring. Fig. 12 shows the bobbin case in the loop-taker, with the bobbin-holder thrown open. The automatic thread controller is actuated by the presser-foot through the medium of the presser-bar, so that the controller gives automatically more or less spread, according to the varying thickness of the goods. This machine is provided with a knee presser-lifter, by means of which the operator can at any time raise and lower the presser-foot by a movement of the knee, leaving both hands free for manipulating the work.

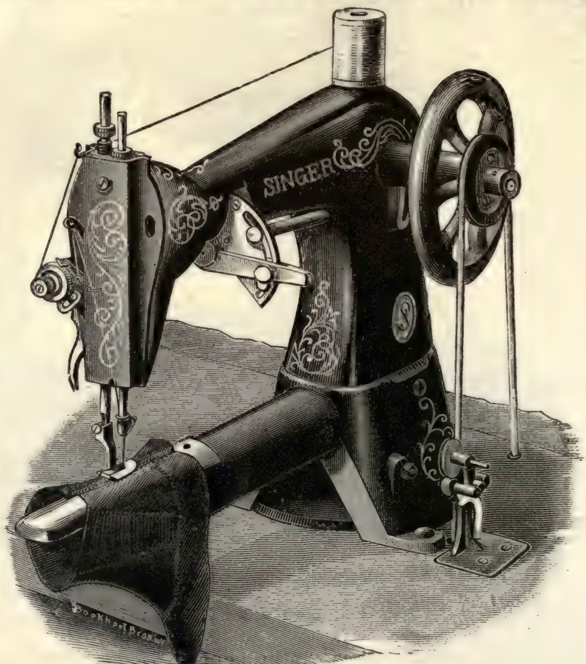


FIG. 14.—Cylinder machine.

The Willcox & Gibbs Straw-hat Machine makes practically a concealed stitch. It has a claimed capacity of 1,000 hand stitches per minute. It produces all sorts of plaits, from the coarsest "rough-and-ready" to the finest "Florence Milans." This is secured by compensating action between the threader, looper, and presser-foot, whereby the needle automatically adapts itself to the thick-

ness of the plait operated upon. The double needles operate from below, and carrying the thread upward through the straw, a looper takes the thread from the threader, and passing over, a small double stitch is made on the upper side, almost invisible, and a long triple stitch on the under side. The hat can be shaped while being stitched.

Two-needle Machines.—A machine of this class, Fig. 13, made by the Singer Manufacturing Co., is a development of the regular automatic chain-stitch machine. It has two needles, and their stitch-forming mechanism, the hook being underneath, is so arranged as to pick up both threads. The gauge, or distance, from one needle to the other can be varied by intervals of $\frac{1}{32}$ in. from $\frac{1}{16}$ in. to $\frac{5}{8}$ in., by substituting feeds, throats, and needle clamps suitable for the required width between seams. These machines are used in corset work, for staying shoes, and for all manner of double seams. A reel is provided for carrying tape or staying material. The same result is obtained by having two chain-stitch machines attached to a base, one being adjustable in relation to the other, so that the width between seams can be varied from $2\frac{1}{2}$ to 16 in., and the length of stitch from 8 to 30 to the inch. Another form of two-needle machine, made by the Singer Co., called the "three-stitch zig-zag machine," makes two rows of stitching, and three lateral stitches in each direction before reversing, and can be fitted to make less or more stitches.

The Singer Two-needle, Two-shuttle Sewing Machine.

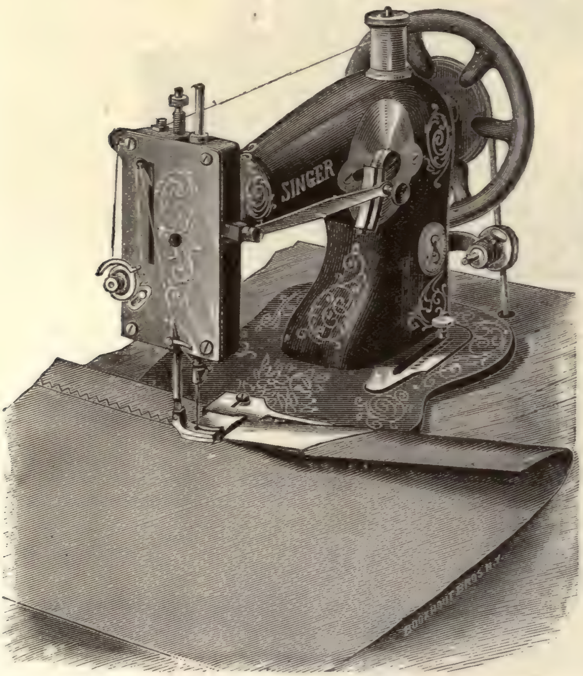


FIG. 15.—Overseaming machine.

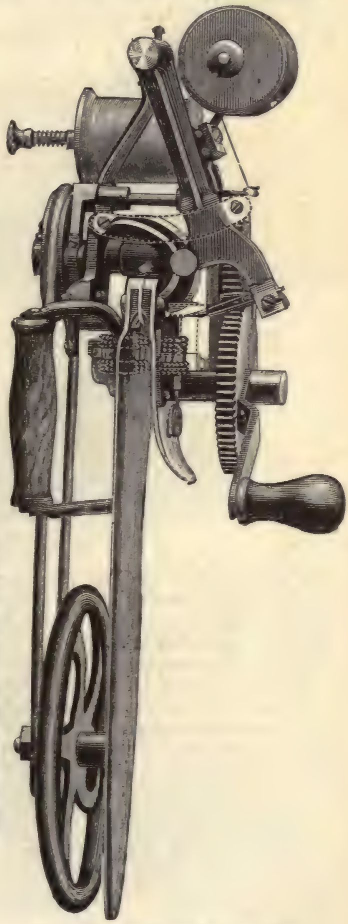


FIG. 16.—Carpet-sewing machine.

—This is a lock-stitch machine, having oscillating shuttle mechanism, and is fitted with two needles set to any desired gauge, with two shuttles (right and left) to correspond, and both actuated by the same shaft. It makes two complete and uniform rows of stitching, and is used in making shirts and corsets, India-rubber clothing, etc.

The Singer Cylinder Machines, Fig. 14, are used for stitching many articles which cannot be stitched upon a flat surface, as elastic gores and back seams in shoes, legs of trousers, and other work in which it is necessary that the thread should pass from and to the inside of a cylindrical or concave surface. They have the oscillating mechanism; are fitted with a reverse stitch regulator, so that the work is fed either up or off the arm, and are made with both wheel and drop feed for feeding around the arm, right or left.

Over-seaming Machines.—A machine of this class, for over-seaming hosiery, knit goods, etc., is manufactured by the Willcox & Gibbs Sewing Machine Co. It has a knife which trims in advance of the needle, which passes alternately through the fabric and over the edge. Two selvage edges can be united in this manner and afterward opened out, leaving a flat seam, without ridge, or two pieces of fabric may be laid flat and their edges joined by the alternate stitches as the needle passes from one to the other. Fig. 15 shows the over-seaming

machine made by the Singer Manufacturing Co. It has oscillating mechanism. On the front of the arm is a slotted lever, worked by a cam within the arm. Hinged to this lever is a pitman connected at the reverse end with a rocking frame, through which the needle-bar operates. The pitman communicates the to-and-fro movement of the lever to the rocking shaft, thus giving the needle-bar the same movement, which may be extended or entirely thrown off by altering the adjusting thumb-screw seen in the cut. This machine is used for sewing cloth, leather, carpet, or knit goods, binding, and especially for overcasting the raw edges, left over after seaming up.

Carpet-sewing Machines.—The machine shown in Fig. 16, and made by the Singer Co., comprises the latest improvements in machines used for this purpose. It is fitted with a saddle device, so that it rides upon the edges of the carpet. The carpet to be sewed is

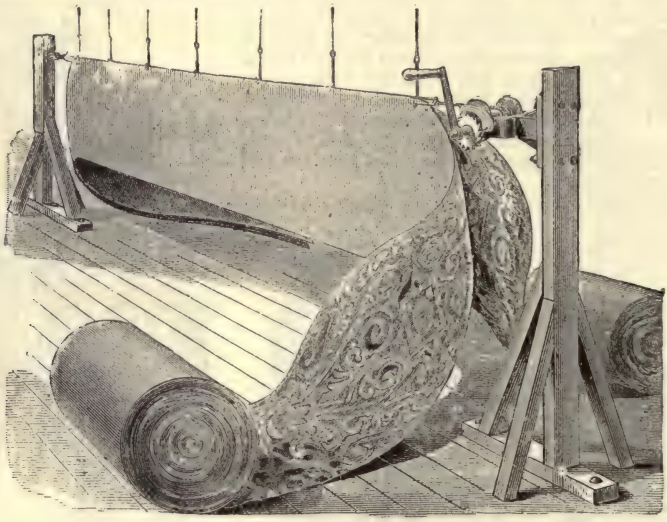


FIG. 17.—Two-needle carpet sewing.

suspended, edge up (Fig. 17), between two clamps attached to upright posts, one of which is stationary, and the other fastened to a windlass, by which the carpet is stretched taut. The saddle is placed on the tightly-drawn edges. With the left hand the operator grasps the handle shown in cut. The machine, as it is operated, feeds itself along the edges of the carpet. The character of the stitch permits the opening of the carpet flat while retaining a complete union of its edges.

The 16-ft. canvas and belting sewing machine, designed by the Singer Co., is probably the largest sewing machine ever built. It has an oscillating shuttle, two needles, and will stitch goods from $\frac{1}{8}$ in. to 1 in. in thickness, and any width to $7\frac{1}{2}$ ft. It is fitted with roller feed, and a guide adjustable for various widths, for making parallel seams.

See also BOOK-BINDING MACHINES and LEATHER-WORKING MACHINES.

Shaft-rounding Machine: see Molding Machines, Wood.

Shaper: see Molding Machines, Wood.

SHAPING MACHINES, METAL. *The Hendey Traverse Shaper.*—Fig. 1 shows a heavy shaper built by the Hendey Machine Co., Torrington, Conn., and designed for railroad and other heavy work. It has a stroke of 30 in., and can be set to vary length of stroke while in motion. The saddle has a traverse on the bed of 72 in. Feed works at each end move the saddle back and forth. The saddle can be run fast by hand from one end to the

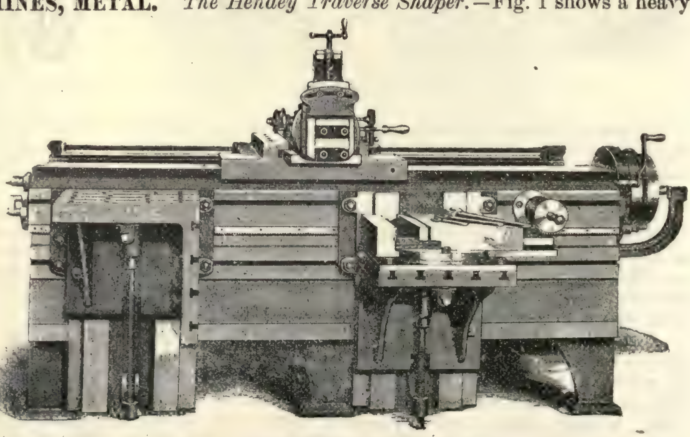


FIG. 1.—The Hendey traverse shaper.

other when desired to change the position on bed, each turn of crank moving it $2\frac{3}{8}$ in. The head has automatic vertical feed, and can be set to any angle. The circular arbor also has independent feed, and is operated from the pulley end of the machine. The tables are raised and lowered by screws, and the aprons on which the tables work are moved on bed by a rack and pinion. The aprons have a bearing low down on the bed, to insure solidity when taking a heavy cut. The vise jaws open 15 in., and are 15 in. long. The vise is graduated, and swivels on a heavy base-plate.

Wright's Friction Shaper.—Fig. 2 shows a new form of shaper made by J. D. Wright & Sons, Brooklyn, N. Y. The driving shaft seen on the side of the machine carries two loose pulleys ; the forward one is the cutting pulley and has two steps, giving two speeds in cutting, and carries an open belt. The rear pulley is the return pulley, and carries a cross belt from a large pulley on the countershaft, giving a quick return. These pulleys are thrown into and out of gear by a friction clutch. The side bearings for the shaft are adjustable for wear, and

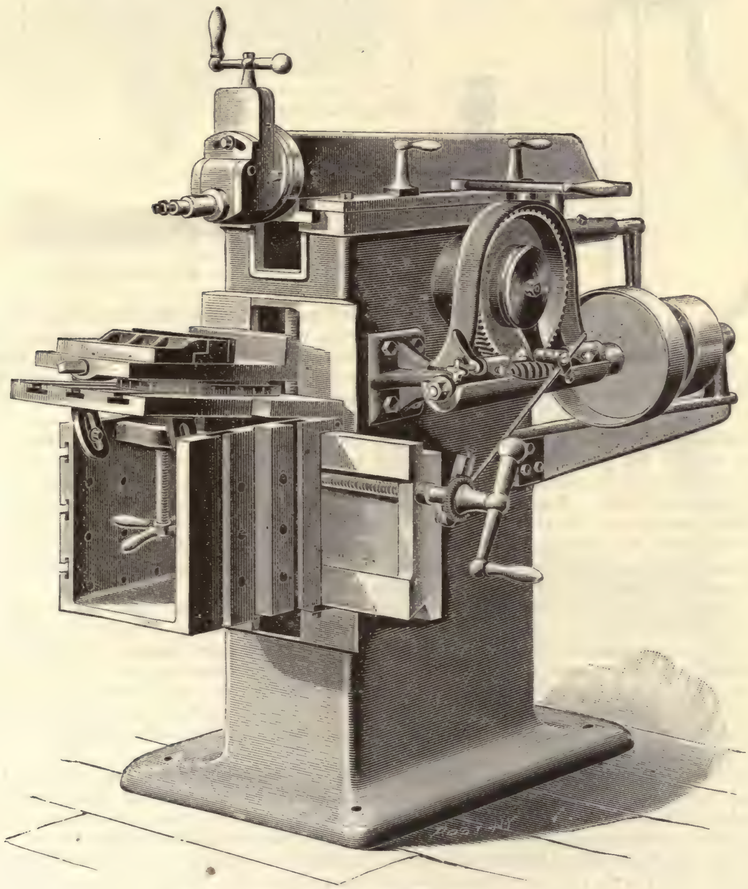


Fig. 2.—Wright's friction shaper.

have wicks drawing oil from the cup beneath. The worm runs in oil. It is of steel, hardened and polished, and meshes in the large phosphor-bronze wheel. The wheel is secured to the end of the rack shaft, passing through the base of the machine, to which are secured the two rack wheels. The teeth of the rack are at an angle to the line of the shaft, and are right and left, preventing any side thrust. The loose pulleys on the driving-shaft are turned on the inside of their rims to a taper. The outside of the friction-rims is turned to the same taper, and in action is forced into the loose pulleys by a shifting-fork. The shank of the fork has a certain amount of spring, which relieves the friction and pulleys from the shock or jar of the ram when reversing its motion. The cross-feed is given to the table by the screw ratchet and rod which is secured to the lower part of the disk, which disk is compressed between leather disks. The friction of the leather causes the feed-disk to move with the wheel until stopped by the fixed pin on the rear bracket, or by the adjustable threaded stop pin on the forward bracket. The table is secured to the cross-head in the usual manner,

but the top plate is hinged at the rear end of the open table, and is raised by the screw shown, and is clamped when in position by screws passing through slots in the drop pieces shown on the under side of the plate.

Sheaf Carrier : see Harvesting Machines, Grain.

SHEEP-SHEARING MACHINE.—Fig. 1 shows the sheep-shearing machine of Burgon & Boll, Sheffield, England, installed complete ; Fig. 2 shows a few links of the flexible operating chain ; and Fig. 3 is a larger view of the shears. The fly-wheel when in gear actuates the friction wheel, marked *c*, fitted with a spindle having a gimbal joint at its base to connect it with the flexible chain, which is contained within a hempen tube. Another gimbal joint at the lower end of the chain unites it with the shears, which are like those of a horse-clipper and formed to be held in the hand of the operator. The under teeth of the shears, ten in number, remain stationary, while three upper teeth reciprocate rapidly upon them, something like two thousand times per minute. With the machine it is easy to avoid cutting the skin of the sheep, while gaining more wool and working more rapidly than with hand work. The hanging cords, *a* and *d*, are for starting and stopping the machine by means of the shifter, *b*. The flexible chain is of hardened steel.

Fig. 2.

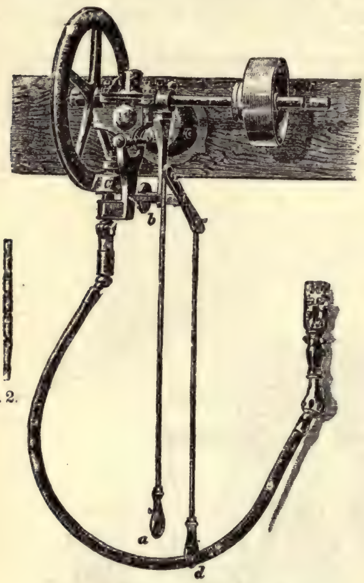


Fig. 1.—Sheep-shearing machine.

Fig. 3.—Detail.

SHINGLE-MAKING MACHINERY. In the manufacture of shingles nearly every machine, except for jointing the butts, is a sawing machine; the difference being as to whether the saws are on vertical or horizontal arbors, and whether one saw takes care of one or more than one block. Machines with two or more saws cut from four to ten bolts at one time. The machines of smaller capacity usually present the bolt to the saw and withdraw it by a reciprocating motion, those of larger capacity using a rotary motion. Among the former, the principal points of difference are as to whether the block is presented end on or side on; and in minor details of varying the taper, thickness, etc.

For making sawed shingles there are several classes of machines. One of the most simple has a circular saw upon a vertical arbor, belted from below, and a sliding carriage presents the bolt endwise to the saw, so as to cut with the grain of the wood instead of across it. This table or carriage has an adjustment by which either the front or the back end may be tilted, so as to saw a shingle which is tapering in its length ; and there is provision for changing the thickness of cut without altering the taper, or for varying both. Such a machine will cut 3,000 to 4,000 cedar shingles per hour; and it is also adapted for sawing heading and box stuff.

In the shingle machine made by Adams & Sons the saw arbor is vertical, and the block or bolt is borne between dogs at the end of an arm vibrating in a horizontal plane and presenting the side of the block to the action of the saw. The taper is given by tilting one end of the table bearing the block by a foot lever ; this gives the requisite degree of taper to one shingle, and the table being brought back by a spring when the foot is taken off the treadle after one shingle is cut, the next shingle is cut with the butt coming at the opposite end of the bolt from that of the first one cut. Thus every other shingle has its butt to the right ; and the saw cuts slanting at every other cut, and parallel on the intermediate cuts.

A shingle and head-cutting machine brought out by S. Adams & Son has the axis of the circular saw which does the cutting inclined slightly from the vertical, and the top or table is semi-circularly inclined from the horizontal. Along the top there slides a clamping table which holds the bolt which is to be cut; the bolt being placed crosswise of the machine so that its side is presented to the action of the saw. The bolt being clamped at the lower end of the inclined table, every time that the table is drawn forward the shingle or heading is sliced from it, and drops clear of the saw. There is suitable adjustment for giving any thickness or degree of taper, and the machine will cut with the butt first on one end of the block and then on the other, or may be set so as to cut the butts continuously from either end, as desired. The capacity claimed is 3,000 shingles per hour from suitable blocks, or 60 shingles per minute from blocks 8 in. wide. The carriage is moved up over the saw by a pinion running in a rack gear until the saw has passed through the block, when the pinion is automatically released and the carriage moves back by gravity. Then the dog opens, the bolt or block drops on the platform, which is tilted by a ratchet wheel, the pinion engages the rack

again, and the carriage moves the block against the saw. There are two feeds, one for hard and the other for soft wood.

In one of the most important of the shingle-cutting machines made there is a large horizontal disk, driven by gearing over the top of a frame having at two opposite points in its circumference a circular saw. The disk has dogging provision for ten bolts at once, and each of these is brought in turn to first one and then the other of the horizontal circular saws, making a shingle from each bolt at each presentation to the saw, or twenty shingles for each rotation of the circular traveling table. There are several modifications of this machine, which is made by Perkins & Co.

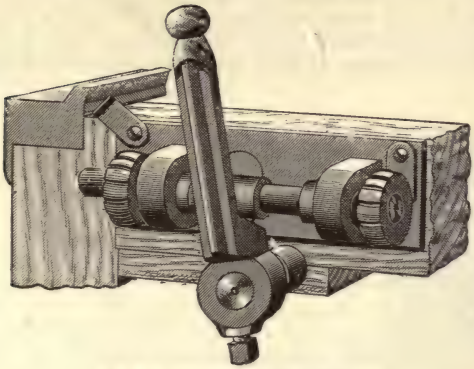


FIG. 1.—Shingle tapering device.

An attachment for regulating the throw or stroke of the tilt-table lever of a shingle machine may seem a trivial matter, but it is very important in such machines to have a device which can be changed without the necessity of a wrench, at the same time being positive to set and lock. In this, shown by Fig. 1, the handle has cast to it a projection that engages in a groove in the enlarged part of a sliding bar that is placed between two thumb-nuts, which latter screw through the lugs on the casting; and the enlarged part of the sliding bar strikes the end of each nut as the lever is tilted one way or the other. Screwing the thumb-nuts one way or the other gives the lever more or less throw, and therefore gives the tilt-table more or less taper. These thumb-nuts are grooved on their edges, and a swinging notch or lock engages with one of the grooves when it is hanging down, thus making it impossible to turn the nuts, and the weight of the stop causes them always to remain in this position unless raised by hand.

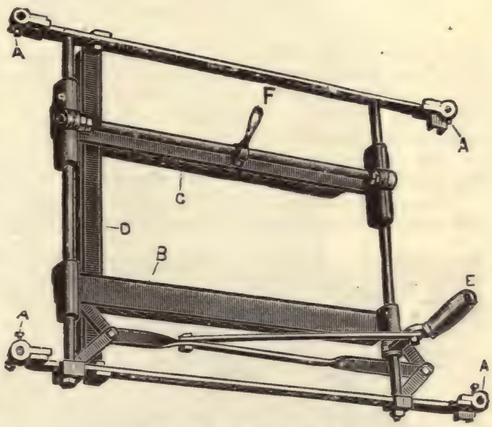


FIG. 2.—Stealer carriage.

What is known as a stealer-carriage for shingle machines is a device for dogging a board or other thin piece of material, and presenting it to the action of the single saw so as to utilize the thin material that would otherwise have to go to the steam burner. One made by J. C. Simonds & Son is shown in Fig. 2. The carriage is so constructed as to wedge or lock the board or shingle on three sides, and instead of wedging it lengthwise, as is usual with such clamps, it holds it crosswise. The shingle that is being sawed is not dogged at all, but all the dogging is done on the piece above it and on the last piece, or the piece that is left after all the shingles are cut out of the board, thus making it impossible to spring the shingles. This carriage will clamp and hold a piece that is only $\frac{1}{8}$ in. thick at the thick end above the saw. The split or wedge piece that is left after the last shingle is cut is held in the carriage and drawn back from over the saw.

Shoe Machinery: see Leather-working Machinery.

Shoe Stamp: see Ore-crushing Machinery.

SHOVEL, RAILROAD SNOW. An apparatus for removing snow from railway tracks. Figs. 1, 2, 3 illustrate the Leslie rotary shovel. Fig. 1 shows the machine in section, and Figs. 2 and 3 show its appearance when actually at work.

A stout frame of heavy I-beams is mounted upon two four-wheeled diamond trucks, the whole construction being of extra strength. This frame carries a large locomotive pipe boiler, with a firebox which extends the full width between the wheels. This boiler supplies steam in two 17×22 cylinders, with Walshehart valve motion. Each cylinder works a short shaft, on which is fast a bevel wheel 33 in. in diameter at pitch line. Each of these bevel wheels gears into a larger bevel wheel, $49\frac{5}{8}$ in. in diameter at pitch line, fast on the main shaft, thus driving the knife wheel placed in the front of the machine. This wheel is 10 ft. in diameter, and is set in a round casing, with a flaring, square front, 10 ft. wide and the same height, which is made of $\frac{1}{2}$-in. steel plate. This casing serves to cut the bank vertically on each side, by its corner gussets; the snow which the wheel cannot reach is carried to the knife wheel. The rotary wheel contains a hub upon which are placed

twelve radial plates, in the shape of an immense fan wheel. Upon the front of these radial plates are placed an inner and outer series of knives. These knives are pivoted on radial pins, and the surfaces of the knives being inclined to one another, the knives are canted when they encounter snow, and are set so as to slice the snow off the bank on to the fan, the centrifugal force of which causes the snow to fly to the outside of the fan-wheel, and as the latter is surrounded by a casing, the snow can only escape when an opening is provided for it. This opening is at the top of the wheel, immediately behind the headlight. The opening is provided with a movable hood, so that the stream of snow can be regulated and made

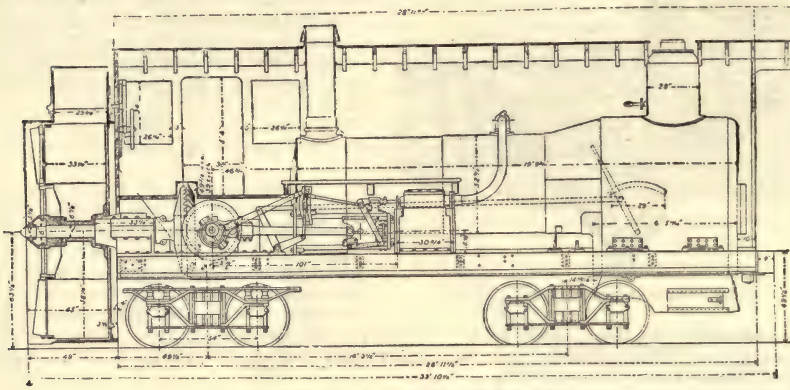


FIG. 1.—Leslie rotary snow shovel.

to fly either to the right or left of the track, and at any desired angle. The rotary, when in operation, is in the charge of a pilot, who stands on the platform in the front end of the cab, from which he has a full view ahead, as well as on each side of the track. By a system of signals he controls the engineers on the rotary and locomotive which pushes it, and by a hand wheel can alter the position of the hood that directs the stream of snow to either side. He has also charge of the ice breaker and flanger for cleaning the rails and flanges after the main body of the snow has been removed by the rotary.

The ice breaker is a stout plate of steel, hanging in front of the front wheel of the front truck, and so attached to the journal box and frame of the truck that it rises and falls with the

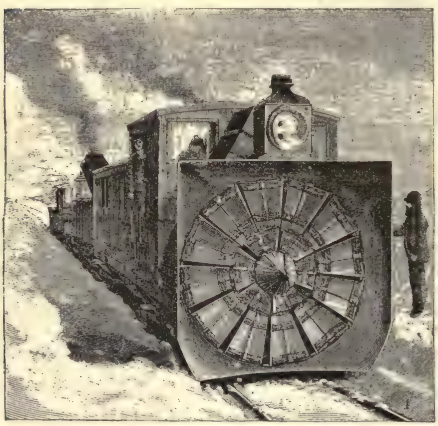


FIG. 2.—Elevation.

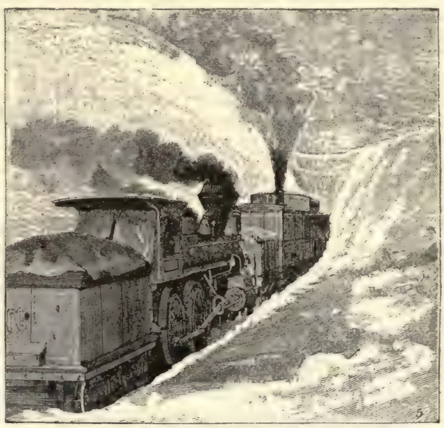


FIG. 3.—Shovel at work.

movement of the front truck wheels, and consequently maintains a fixed position about half an inch above the top of the rail. The ice-breaker and the flanger, which follows it, can be raised and lowered by means of a small steam cylinder, which is supplied by steam from the boiler of the rotary. The flanger, which clears out snow from both sides of the rail for a distance of about 12 in., is attached in a somewhat similar manner in rear of the rear wheel of the front truck. Any ordinary locomotive tender can be attached to the rotary for the purpose of carrying water and coal for the supply of its boiler.

The weight of the machine complete is 110,000 lbs. It is in use on many of the largest railroads of the United States and Canada.

Siamese Connection : see Fire Appliances.

Signals, Railroad : see Switches and Signals.

Silicon Bronze : see Alloys.

Silver Milling : see Mills, Silver.
Sizing Screen : see Ore-dressing Machinery.
Slate Picker : see Coal Breakers.

SLOTTING MACHINES, METAL. *Newton's Rack-driver Slotting Machine.*—Fig. 1, shows a new slotting machine built by the Newton Machine Tool Works, of Philadelphia. It is intended for finishing work above 18 in. in height, and is especially adapted for slotting large forgings. The tool is unusually heavy. Large machines with a crank stroke have generally not been successful. To overcome the difficulty of the ordinary rack-driven machine, and the crank slotting machine, these machines are built with a rack, but,

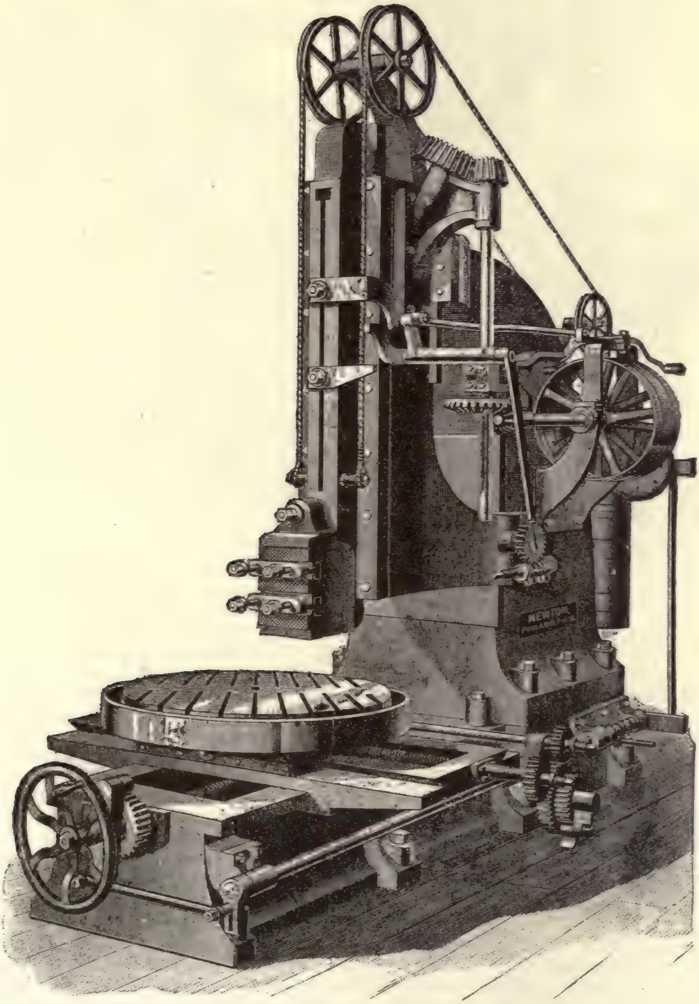


FIG. 1.—Rack-driver slotting machine.

instead of having a pinion or bull wheel working into it, it is driven with a spiral pinion, which is driven through angular bevel gearing, which gives a very even, steady stroke and great power. The machines are capable of taking a full stroke, up to their capacity. The belt velocity is 110 times greater than the movement of the cutting bar. The feeds are arranged automatically, and can be worked by hand. A valuable feature of these tools is the extension of the bed, allowing the carriage to be moved some distance away from the cutting bar. The cutting bar is counterweighted and has a quick return.

Newton's Six-inch Slotting Machine.—Fig. 2 shows a short-stroke slotting machine. The cutting bar is counterweighted, and can be adjusted, and is provided with Whitworth's quick-return motion. The circular carriage has a full bearing on the under saddle, the

worm-wheel being in the center of the saddle. The machine will admit work 23 in. diameter and 10 in. in height. The circular carriage is 17½ in. in diameter, and is made very heavy. Both automatic and hand feeds are provided.

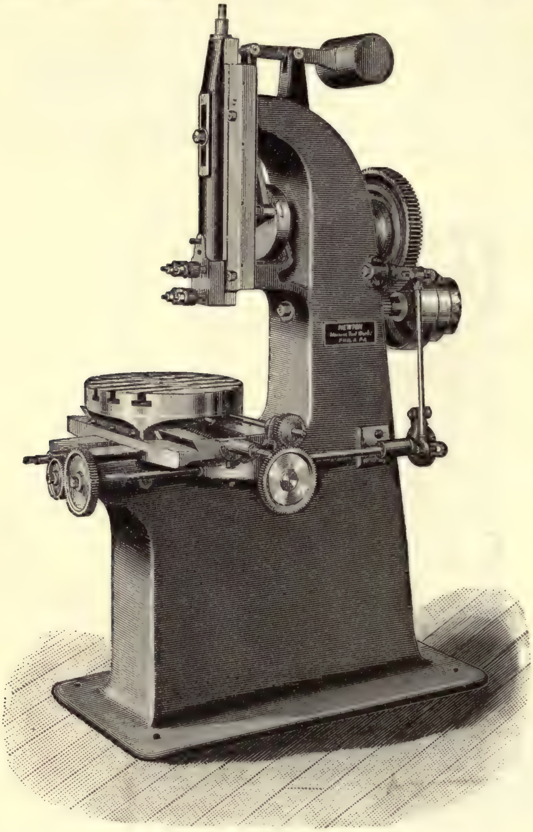


Fig. 2.—Six-inch slotting machine.

SOAP-MAKERS' MACHINERY. There are two well-known processes of soap-making, that by long-continued boiling, and the so-called "cold process." While "cold-process" soap can be made with a much simpler and cheaper plant than regularly boiled soap, it requires a higher grade of stock to make a merchantable article, and as rosin has seldom been successfully used in "cold-process" soap, it is usually cheapened by adding silicate of soda. Of all fillers, sal soda is probably the most satisfactory, as it will soften hard water and does not render the soap so sharp and harsh to the skin as does an excess of uncombined or free caustic alkali. A soap moderately filled with sal soda will generally give better satisfaction than a soap not filled at all. In soap kettles for boiling soap, good practice allows 25 cub. ft. content for every 1,000 lbs. of finished soap the kettle is to turn out in a boiling. While exact data are wanting, it is probably nearly correct to allow one horse-power boiler capacity for every 1,000 lbs. of finished soap to be turned out in a single boiling. A criss-cross coil in the soap-boiling kettle is just as effective and much cheaper than a spiral one of the same heating surface.

A high-grade toilet soap can be made from cuttings and scraps of a *good* quality of boiled soap, by dry remelting to get rid of excessive water. For this purpose the soap stock should have no, or but little, filling. Cuttings and scraps of "cold-process" soap, especially if filled with silicate of soda, cannot be successfully remelted, as the grain becomes coarser. They may be worked up with a new batch of soap, however, or can usually be disposed of to laundries, etc.

The formation of "bags" in "cold-process" soap, it is said, can be prevented by passing a hand crutch back and forth longitudinally through the framed soap several times. After the soap is cut into cakes it is racked and allowed to form a skin by action of the air. Different soaps will require different lengths of time, and the state of the weather will have considerable to do therewith. If possible, select a clear, dry day for pressing, and avoid a clammy, soggy day, as on such days all soap sweats and becomes frothy in pressing.

To prevent sticking of the soap to the dies, it is necessary to sponge the dies or soap in some liquid in which soap is *not* readily soluble. The best way is to sponge the cake on both face sides. For sponging, oil of myrbane and oil of citronella, either singly or mixed, have been used. Salt water, however, is better, and weak acetic acid (vinegar) is best.

Fig. 1 represents a machine for making soap by the "cold process," remelting and crotching soap scraps, melting and mixing rosin, rendering tallow, etc., manufactured by Messrs. H. W. Dopp & Son, of Buffalo, N. Y.

The steam jacket and inner shell are cast in one piece, having a number of stays between the inner and outer shell; there is a large outlet in the center of the bottom for the discharge of the contents. A steam-heating radiator, composed of a series of cylindrically arranged pipes having open spaces between them, is placed in the center; through this radiator steam passes directly to the jacketed part of the kettle, which can be cut off from steam supply so that the inner cylinder only has steam. A conveyor screw is placed in the center of this radiator, which surrounds the screw. As soon as a portion of the soap is melted, the screw is set in motion, thereby lifting the soap up and dumping it over the top of the casing surrounding the screw, when the centrifugal force forces it out of, or through, the open spaces left between the pipes. The large scraps are carried up and are wedged in

between the open ports at the upper end of the radiator. The constant motion of the screw shears the pieces off, and thus, in comparatively short time, the largest scraps are completely cut up, and the whole kettleful of soap will be thoroughly melted and crotched ready for framing. The transferring of the soap into a crotcher after remelting the same, is here overcome, and the two operations are finished in one. Moist steam may be passed at will

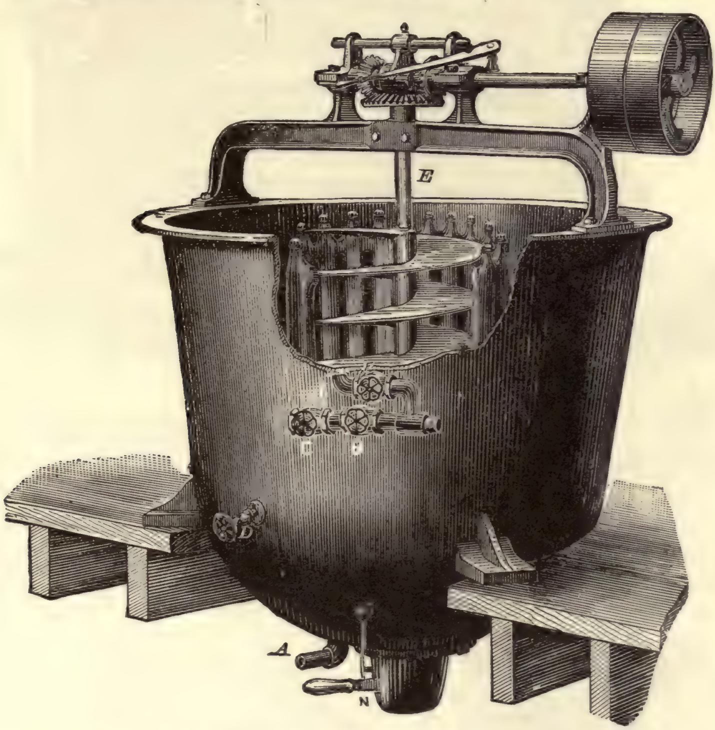


FIG. 1.—"Cold-process" soap machine.

through the soap scraps, etc., to moisten them, if necessary. Cold water may be passed into the jacket and radiator to facilitate the cooling of the soap. The conveyor screw is worked by power forward or backward by shifting the clutch that drives the bevel gearing.

Fig. 2 represents a rendering and refining kettle for making small batches of fancy toilet soap; rendering, refining, cooling, and mixing lard; boiling and mixing oils, varnishes, etc. It consists of a steam-jacketed kettle, provided with an agitator so constructed that it can easily be removed from the kettle and swung out of the way when no agitator is required, for or cleaning the machine.

FIG. 2.—Refining kettle.

An upright provided with a rack is screwed into a bracket, which is cast on the kettle. A pinion, operated by a hand wheel, engages with the rack, and thus the agitator can readily be raised out of the kettle. On reaching the top it can be swung to one side out of the way, and the kettle can be used for boiling and all purposes to which a steam-jacketed kettle can be put. The agitator is a conveyor screw, surrounded by a cylindrical casing. By loosening a set-screw, the conveyor screw can be withdrawn, and the machine cleaned.

An improved form of soap frame, Fig. 3, is made of No. 10 sheet-iron, heavily braced with angle irons to prevent bulging or buckling of the sides. The ends are attached to the bottom in such manner as to be easily detached. The whole is firmly bound together by hinged rods provided with fly nuts as illustrated. The frames can be set up or knocked down in a few moments. Two bottoms are supplied with each set of sides and ends, so that the soap can remain on one bottom for cutting, while the other bottom and frame are ready to receive a fresh charge of soap.

Fig. 4 represents a novel form of soap press, capable of pressing a bar of soap 14 in. long,

weighing from 3 to 4 lbs. It has a single-acting steam cylinder placed underneath the bed

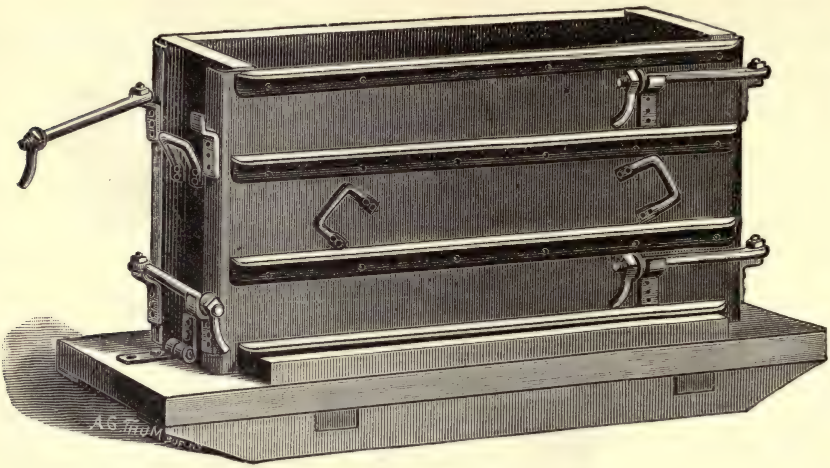


Fig. 3.—Soap frame.

in such position that its piston, by means of a roller attached to the end of the piston rod, acts upon a cam surface of the swing or pendulum lever, as indicated. A hook, attached to the piston rod, engages with a stud on the swing or pendulum lever and prevents the latter from recoiling after having returned from giving the blow, as it can not fly back without pulling out the piston. Thus, vibration of the upper die block is prevented. The steam supply pipe enters a governor or regulator, which can be set by hand wheel, so that the press gives a blow of required force. When this has once been set, the press cannot give a stronger blow than that for which it is set, no matter how much steam pressure the boiler may supply. To the right of this governor is shown a balanced valve steam trap which drains off all condensed water and insures the admission of dry steam only to the cylinder. The admission of steam is controlled by a foot treadle shown at the right of the cut. The handle serves to control the exhaust in such manner that the pendulum lever returns with just enough force to eject the pressed soap and no more. The ejection of the soap is accomplished by a cam, which is pivoted at one end to the pendulum lever, and clamped to the latter by a jam nut and arcs. Against this cam works, by means of a roller, a lever which, with its other end, actuates the center lifting bolt. By unclamping this cam, shifting it up and down, and reclamping, the height to which the soap is lifted is regulated. This arrangement lifts the soap so gradually that there is no danger of throwing the cake of soap out against the upper die block and defacing the impressson, no matter how fast the press is worked. By throwing back hook, and raising the foot-rest, the press is at once transformed into an ordinary foot press.

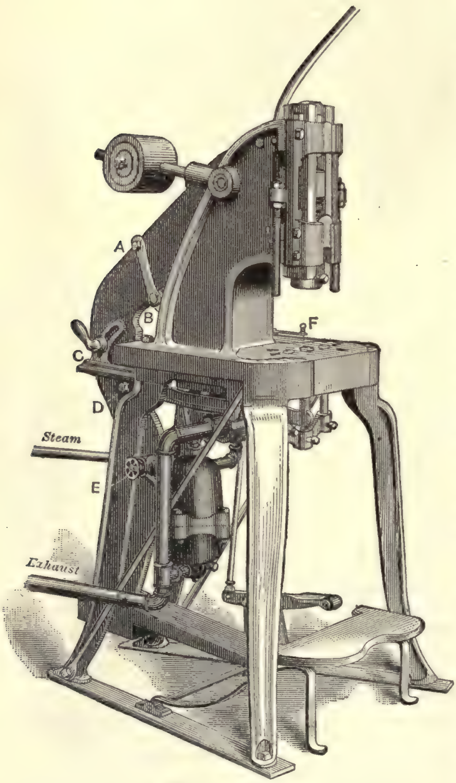


Fig. 4.—Soap press.

Two of the most useful works on soap making are: Brannt's *Manufacturing of Soap and Candles*, H. C. Baird & Co., Philadelphia, Pa.; and Gardner and Cameron's *Soap and Candles*, P. Blakiston, Son & Co., Philadelphia, Pa.

Journals containing items of general interest to the soap trade : *American Soap Journal*, Chicago, Ills., and *Oil, Paint, and Drug Reporter*, New York, N. Y. We are indebted to Messrs. H. W. Dopp & Son, of Buffalo, N. Y., for the foregoing information.

Speeder, Spindle, Spinning Frame, and Spooler : see Cotton-spinning Machines.

Spreader : see Rope-making Machines.

Stacker : see Threshing Machines.

Staking Machines : see Leather-working Machines.

STALK CUTTERS. Cornstalks, where the growth has been rank, are an obstacle to

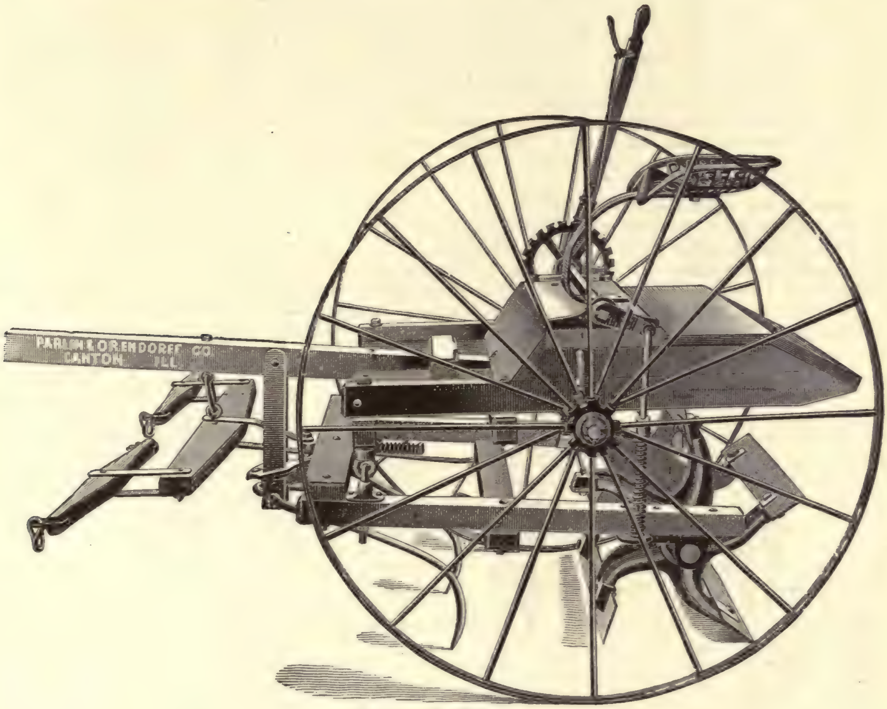


FIG. 1.—Stalk cutter.

the plow. The stalk cutter, by means of draft hooks pendent under the frame, combs the stalks into line, and then, by means of transverse revolving knives, chops them into short lengths, which cannot foul the plow and are easily turned under by it. The implement for this use formerly consisted simply of a roller armed with knives parallel with its axis and projecting from its face, and, subsequently, mounted eccentrically with the axis of the roller, projecting through slots in the roller when coming to the ground, and drawn within the face of the roller when passing upward and over. But it has been transformed from a very imperfect to an effective machine by the improvements shown in Fig. 1.

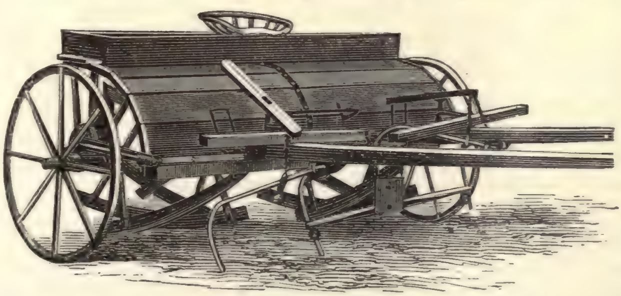


FIG. 2.—Stalk cutter.

Parlin & Orendorff's Stalk Cutter.—The working parts are mounted on a strong sulky. The lower floating frame carrying the bladed reel is attached in front to the main frame above it by draft rings at the corners, and is pressed down by a pair of strong spiral side springs, which occasion a successive rebound of each of the five blades downward after every recoil from the resistance of the stalks to the stroke of the blades. This automatic rebound, aided by the resistant inertia of the whole fabric, chops the stalks thoroughly, which is impossible merely by the weight of the machine

steadily applied. To relieve the team from undue jerking under the chopping action described, the doubletree is connected by a spring to the draft rod of the machine. The cylinder is covered for safety from the knives, and the cover forms a box for ballast, to add weight when needed to insure thorough cutting. The floating frame and cutters are raised and held up by a lock lever when not required to cut. The knives are set tangentially backward, at that angle which insures the best cutting result. The knife-reel is rotated by contact with the ground as the machine advances. The same class of machine is used on cotton land to fit it for the plow by cutting the cotton stalks into short lengths in the same way, but owing to their toughness and hardness is necessarily made much heavier and with stronger reaction side springs than is necessary for corn-stalks.

Avery's Stalk Cutter, Fig. 2, has six knives arranged spirally around their axis to effect constant pressure on the ground, and thus avoid jolting; also to distribute the work evenly by cutting few stalks at once; and to lighten work by cutting them obliquely with their grain. The cutting apparatus presents, when viewed from front or rear, a profile as shown in Fig. 2, suiting the machine to the usual ridged contour of cornfields. The machine is preferably made wide enough to cut the width of two corn rows, to use two horses and a man, for about as much duty as for four horses and two men with two of the single-row size. The cutters have their axis independent of the ground-wheel centers, and their pressure can be controlled by the lever.

Stamp : see Ore-crushing Machines.

Stamping Machines : see Book-binding Machines.

Stave Jointer : see Barrel-making Machines.

Steamers, Passages of : see Engines, Marine.

STEAM LOOP. The steam loop is the name given to an ingenious device, shown in Fig. 1, for returning the water of condensation from a steam pipe or separator into the boiler. It consists merely of a system of piping, and does not necessarily contain any valves, adjustments, or moving mechanism. The following description of its method of operation is extracted from a lecture by Walter C. Kerr before the Franklin Institute. The principles on which its action depends are as follows : Difference of pressure may be balanced by a water column ; vapors or liquids tend to flow to the point of lowest pressure ; rate of flow depends on difference of pressure and mass ; decrease of static pressure in a steam pipe or chamber is proportional to rate of condensation ; in a steam current water will be carried or swept along rapidly by friction. The water of condensation runs into a separator. (See cut.) The drip from the separator is below the boiler, and, evidently, were a pipe run from this drip outlet directly to the boiler, we would not expect the water to return up-hill. Moreover, the pressure in the boiler is, say, 100 lbs., while in the separator it is only 95 lbs., due to the drop of pressure in the steam pipe, by reason of which difference the steam flows to the engine. Thus the water must not only flow up-hill to the boiler, but must overcome the difference in pressure. The device to return it must perform work, and in so doing heat must be lost. The loop, therefore, may be considered as a peculiar motor doing work, the heat expended being radiation from the upper or horizontal portion. From the separator or drain leads the pipe called the "riser," which at a suitable height empties into the "horizontal." This leads to the "drop leg," connecting to the boiler anywhere under the water line. The "riser," "horizontal," and "drop leg" form the loop, and usually consist of pipes varying in size from ¾ in. to 2 in., and are wholly free from valves, the loop being simply an open hole from separator to boiler. (For convenience, stop and check valves are inserted, but they take no part in the loop's action.) Suppose steam is passing, engine running, and separator collecting water. The pressure of 95 lbs. at separator extends back through the loop, but in the drop leg meets a column of water which has risen from the boiler, where the pressure is 100 lbs., to a height of about 10 ft.—that is, to the hydrostatic head equivalent to the 5 lbs. difference in pressure. Thus the system is placed in equilibrium. Now, the steam in the horizontal condenses slightly, lowering the pressure to, say, 94 lbs., and the column in drop leg rises 6 in. to balance it ; but meanwhile the riser contains a column of mixed vapor, spray, and water, which also tends to rise to supply the horizontal as its steam condenses, and, being lighter than the liquid water of the drop-leg, it rises much faster. If the contents of the riser have a specific gravity of only ·1 that of the water in the drop leg, the rise will be ten times as rapid. and when the drop leg column rises 1 ft., the riser column will lift 10 ft. By this process the riser will empty its contents into the horizontal, whence there is a free run to the drop leg and thence into the boiler. In brief, the above may be summed into the state-

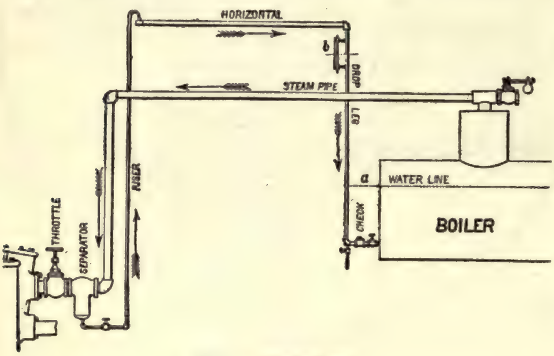


Fig. 1.—Steam loop.

ment that a decrease of pressure in the horizontal produces similar effects on contents of riser and drop leg, but in degree inversely proportional to their densities. When the condensation in horizontal is maintained at a constant rate sufficient to give the necessary difference in pressure, the drop leg column reaches a height corresponding to this constant difference, and rises no further. Thus the loop is in full action, and will maintain circulation so long as steam is on the system, and the difference of pressure and quantities of water are within the range for which the loop is constructed. No water should accumulate in the separator, as it is the mission of the loop to remove it before it assembles into a liquid mass. It is here that constant and vigorous action is of great practical utility, enabling the loop to act as a preventive rather than a device for removing water after it has accumulated. The separator evidently must be of such form as to give the sweep toward and through the loop better opportunity to pick up the entrained water than is afforded the current sweeping toward the engine, pump, or steam-using device. The loop action is practically independent of the distance that the source of supply is above or below the boiler, and also independent of the length of return. It is capable of handling such quantities of water as usually exist in steam systems. It is practically limited by excessive differences of pressure, and by abnormal quantities of water.

Steel : see also Alloys ; Presses, Forging, and Tempering and Hardening.

STEEL, MANUFACTURE OF. *Recent Improvements.*—The one notable improvement in the manufacture of steel in the past ten years has been the successful introduction of the basic process, both open-hearth and Bessemer, the invention of the late Sidney Gilchrist Thomas. In improvement in mechanical details of the manufacture, with the view of diminishing the amount of labor and of increasing the output of a single plant, the record of the past ten years has been one of extraordinary development. In Bessemer works, the use of fluid metal direct from the blast furnaces, without remelting in cupolas, has become most general. A notable invention in this department is that by the late Capt. William R. Jones, of the metal mixer, an immense tilting vessel, lined with fire-brick, in which several ladlefuls of iron from different blast furnaces are poured and mixed, and from which the metal is drawn off as required into other ladles, from which it is poured into the converters. The converters themselves have undergone no essential change, except increase of size. A capacity of 15 tons to the heat is now adopted in the latest works. The old casting pit, with its ingot molds, ladle crane, etc., immediately in front of the converters, is being done away with, and for it are substituted ingot molds placed on cars, and an overhead traveling crane, which carries the ladle of melted steel from the converters to a point above the ingot molds standing on cars at any point in the track running lengthwise through the converter house. This arrangement has been adopted in the latest built works, those of the Maryland Steel Co., at Sparrow's Point, Md., and is about being used in the reconstruction of the Edgar Thomson Works. The ingots, with the metal in their interior still fluid, are drawn by a locomotive to the "stripper ;" a hydraulic machine strips them—that is, pulls the ingot molds off from them, leaving them standing on the cars. When cool enough to be handled by the crane tongs, they are lifted by a hydraulic crane, and placed, still in a vertical position, in the "soaking pits," the invention of Mr. Gjers, of Middlesborough, England, which are underground fire-brick receptacles, heated by the ingots themselves. In Hainsworth's modification of these pits, a small regenerative furnace is placed adjacent to them, by which they may be heated when necessary by the burning of fuel. When the heat of the ingots has been equalized in these pits, the fluid interior having solidified while the comparatively cool exterior is heated to a yellow heat, they are ready for rolling. In most modern mills they are rolled directly from the ingot into a rail, by passing through two or more stands of rolls in rapid succession, without reheating or cutting into blooms. A four-length rail is usually made, which is cut into rails 30 ft. in length at one operation by five hot saws, which simultaneously make the four rails and the two crop ends. The handling of the rail while passing through the rolls is done entirely by machinery, the invention of Capt. Robert W. Hunt, no manual labor whatever being required to lift or turn either ingot, bloom, or rail. Descriptions of the process of rolling, as adopted at the Edgar Thomson Works, Braddock, Pa., and at the Illinois Steel Co.'s works at South Chicago, are given by Captain Hunt in his presidential address before the American Society of Mechanical Engineers, in November, 1891.

The Basic Process.—(See Messrs. Thomas & Gilchrist's paper on "The Manufacture of Steel and Ingot Iron from Phosphoric Pig Iron," which was read before the Society of Arts, in London, in 1882.)

The Bessemer vessel is lined with magnesian lime, which has been previously subjected to an intense white heat, and so brought to a condition of density, tenacity, and hardness as far as possible removed from the conditions of the material generally known as "well-burnt lime," and more closely resembling granite or flint. This material, which for brevity is known as "shrunk lime" (as in course of preparation it shrinks to one-half the bulk of ordinary lime), is used either in the form of bricks or in admixture with tar, as a rammed or "slurry" lining, this being substituted for the ordinary silica brick or siliceous ganister lining of the hematite process.

Before the metal, which may be either employed direct from the blast furnace without intervening remelting, or, if for any reason this is not convenient, may have been remelted in a cupola, is run into the converter, from 15 to 18 per cent. of common "well-burnt" lime is thrown into the vessel. The metal is then introduced and the charge is "blown" in the

ordinary way to the point at which the ordinary Bessemer operation is stopped—that is, till the disappearance of the carbon, as indicated by the drop of the flame.

The dephosphorizing process requires, however, to be continued for a further 100 to 300 seconds; this period of so-called "after-blow," which would be prejudicial both to quality and yield in the ordinary process, being with phosphoric iron (under conditions permitting of the removal of phosphorus) that in which the great bulk of the phosphorus, down indeed to its last traces, is removed. The termination of the operation is shown by a peculiar change in the flame, and checked by a sample of the metal being rapidly taken from the turned-down converter, flattened under the hammer, quenched, and broken, so as to indicate by its fracture whether the purification is complete. A practised eye can immediately tell whether this is the case or not. If the metal require further purification, this is effected by a few minutes further blowing.

The operation is thus, as will be seen, but little different from the ordinary Bessemer process. The differences that have been indicated, viz.: the lime lining, the lime addition, and the after-blow, are, however, sufficient not only to enable the whole of the phosphorus (which would be otherwise untouched) to be completely removed, but the silicon, of which inconvenient and even dangerous quantities are occasionally left in the regular Bessemer process, is also entirely eliminated, while at least 60 per cent. of any sulphur (also untouched in the ordinary process) which may have been present in the pig is also expelled. It is found, too, that the once-dreaded phosphorus is of most substantial assistance in securing by its combustion the intense heat necessary for obtaining a successful blow and hot metal. If it is desired to produce "ingot iron," or a metal differing only from puddled iron by its homogeneity and solidity, the usual addition of spiegel is omitted, or replaced by a half per cent. of rich ferromanganese. The phosphorus is oxidized by the blast, forming phosphoric acid, which, finding itself in presence of two strong bases, oxide of iron and lime, unites with the latter of them to form phosphate of lime, which passes into the slag. Whether or not there is a transitory formation of phosphate, making oxide of iron perform the function of a carrier, is a matter (though interesting theoretically) which it is needless here to discuss. The basic Siemens and Siemens-Martin processes are carried out upon the same lines as the Bessemer process. The dephosphorization is very complete, but the operation takes about 5 per cent. longer than when pure material is used; the proportion of lime required is less than in the Bessemer process, and the wear of the basic hearth, with suitable arrangements, is not excessive. In 1878 there was not even in existence any public record of successful dephosphorization of pig iron. In 1884, 864,000 tons of basic steel were produced. In 1890 the production was 2,603,083 tons. Moreover, in this last year, too, there were also produced, together with the steel, 623,000 tons of phosphoric slag, most of which was used for fertilizing purposes.

The Darby Recarburizing Process.—This process, invented by Mr. John Henry Darby, of the Brymbo Steel Works, consists in a method for adding the required carbon to molten steel by means of pure pulverized carbon, in lieu of the spiegel hitherto used.

The addition of the carbon may be made by any of the following methods:

(1) By the use of a special funnel-shaped filter, which is filled with carbon, and through which the molten metal flows.

(2) By means of a worm, working in a funnel, hanging or standing over the ingot molds, when it is desired to recarburize only a few ingots from a charge.

(3) In the Siemens furnace the carbon is added to the molten steel as it flows from the furnace down the spout, and in the Bessemer process as the metal flows from the converter into the ladle, so that the recarburization takes place, partly during the casting and partly in the ladle. The third method is now used, both on account of its cheapness and exactness. The ground carbon is placed in a sheet-iron funnel, which for a 10-ton charge should be capable of holding about 450 lbs. of good ground coke. The funnel is provided with a sliding valve, at the lower end of which a pipe is affixed, and through which the carbon falls into the stream of metal. The flow of the carbon should be so regulated that the whole of the carbon is in the ladle when two-thirds of the steel has been run into it. The slag must be kept well back, especially in the basic process, to prevent reduction of the phosphorus in the slag. The amount of carbon to be added must be 10 to 20 per cent. in excess of the theoretical quantity for a given percentage. Experiments have shown that in order to increase the carbon 0·05 per cent. in a ton of steel, about 1·6 lbs. of coke must be used. From this as a basis, a table of "charges" may easily be figured out for any given percentage of increase. By this process the use of spiegel is entirely done away with; the amount of ferromanganese to be added, however, is about the same as by the older method of recarburizing. (See "On the Darby Process of Recarburization," by M. A. Thielen, *Journal of the Iron and Steel Institute*, No. 2, 1890.)

The Lash Open-hearth Furnace Plant is illustrated in Figs. 1, 2, 3. It is peculiarly adapted to the use of natural gas. There are 16 furnaces erected in Pittsburg on the Lash system, four of 40 tons, five of 30 tons, one of 20 tons, and six of 15 tons.

The hearth of the furnace (*1*) is made circular, or, preferably, elliptical. The lining of the hearth conforms to the shape of the shell.

The single flues in natural-gas furnaces at either end of the melting chamber are 5 ft. wide, and are simply large passages inclined down toward the bath at a pitch of about 4 in. to the foot, to give the flame a strong guide downward upon the metal. In order to provide a firm support for the arched roofs of the melting chamber and flues leading into it, a water-bosh, made of ½-in.-thick steel plate, is put in the form of a keystone in the arch of

each roof. Natural gas is led into the sloping flues by wrought-iron pipes (*10–17*), and being much lighter than the air, mixes with it in its downward rush into the furnace. The stack (*21*) is placed in such a manner that the flues leading from each end of the hearth (*22–23*), which have checker-work in them, alternately act as regenerators to preheat the air before it enters the furnace. The lower end of the stack is connected by a short flue (*24*) with a four-

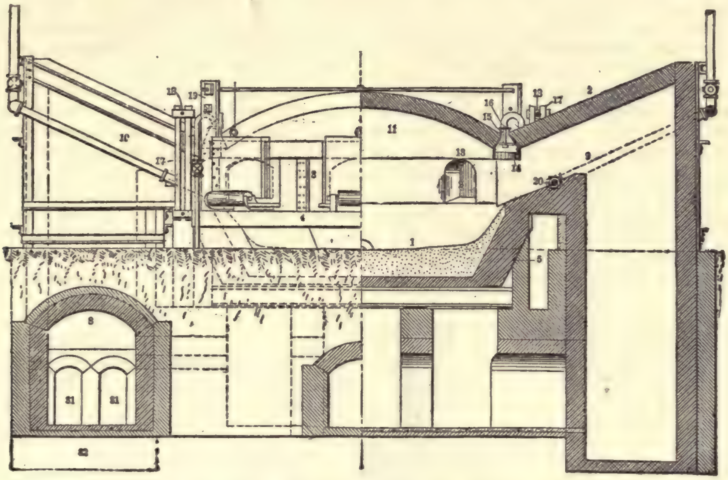


FIG. 1.—Lash open-hearth furnace. Vertical half sections and projections.

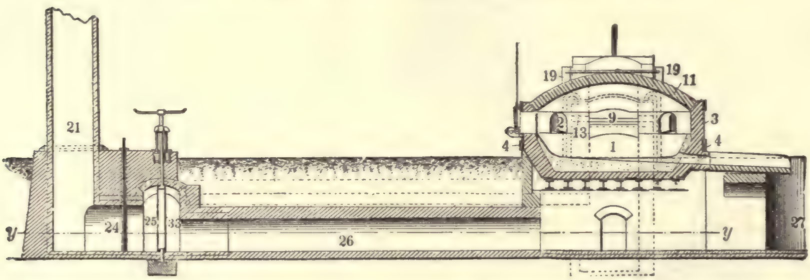


FIG. 2.—Lash open-hearth furnace. Transverse section.

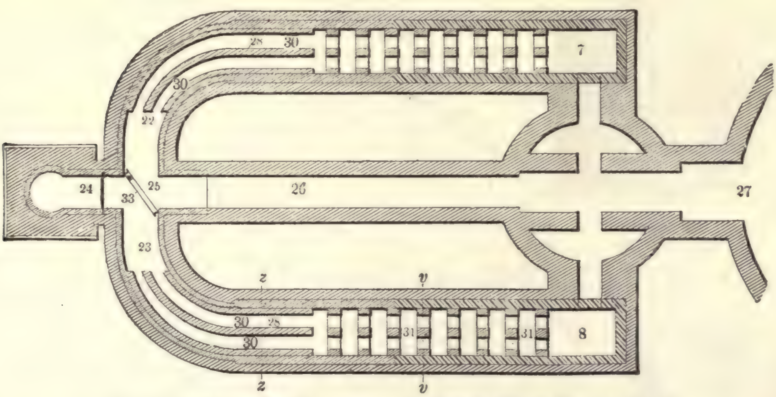


FIG. 3.—Lash open-hearth furnace. Horizontal section on *y*, *y*, Fig. 2.

way chamber (*25*), to which the flues (*22–23*) from each end of the furnace converge, and to which the air duct (*26*) delivers. This air duct (*26*) leads out from the ladle pit (*27*), and passes directly under the hearth, in this way not only heating the air, but giving a free circulation under the hearth, and preventing an excessive heating of the bottom. Along the middle of the flues (*22–23*) leading from the central four-way chamber (*25*) to the opposite ends of

the furnace, is placed checker-work of fire-brick, supported on tiles (*28*), so that the bottoms of the flues are clear openings, giving a stronger draught; but as there is constant tendency of the heated air to ascend, there is a thoroughly uniform heating of the air entering the furnace by this arrangement. The front portions of the flues are provided with a series of double arches. The four-way chamber (*25*) has the air duct (*26*) leading into it permanently open, and is fitted with a three-way valve (*33*), alternately connecting the flues (*22–23*) leading to each end of the furnace with the chimney (*21*) and with the air chamber (*25*), in this way reversing the furnace on the well-known Siemens principle. This three-way valve (*33*) is hollow, and is kept cold by a stream of water running through it, preventing the warping or burning out of the valve, or with the Siemens gas furnace, the direct loss of fuel by leakage to the chimney. The tap-hole of the melting furnace is at about the ground-level, and the metal is conducted, through an inclined spout some 10 ft. in length, to the ladle pit (*27*). The Lash furnaces have all the ordinary and important operations around the furnace on one ground level, the three doors on the back side of the furnace and the two on the front or tapping side being accessible for charging or for repairs to the furnace. A record of 500 consecutive heats, of 50,000 lbs. of stock each, shows that these were charged in an average of 24 minutes per charge, 12 men, or all hands about the furnace, doing the charging from all five doors, which are balanced and arranged to open by levers in the pulpit under the control of the crane boy.

The Batho Furnace is represented in Figs. 4 to 7. It consists of five separate wrought-iron cases, all on one level, lined with fire-brick, which form the outside walls of the four regenerators and of the melting chamber. The regenerators are connected to the melting chamber overhead by means of wrought-iron pipes, running almost horizontally, which are lined with refractory material. The melting vessel is lined with basic material and covered with a roof of silica brick, enclosed in a strong skew-back ring of iron. The gas ports are in the side walls of the melting chamber and the air is carried in through a port in the roof directly over

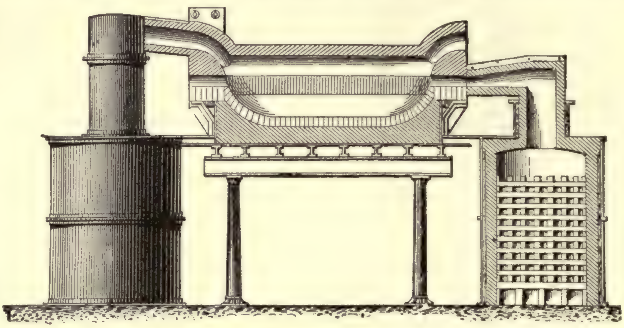


FIG. 4.—The Batho furnace. Sectional elevation.

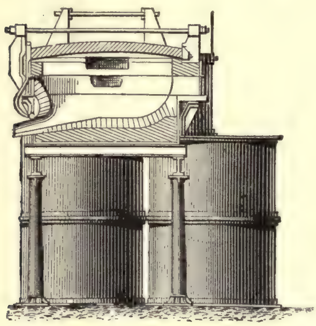


FIG. 5.—The Batho furnace. Cross section.

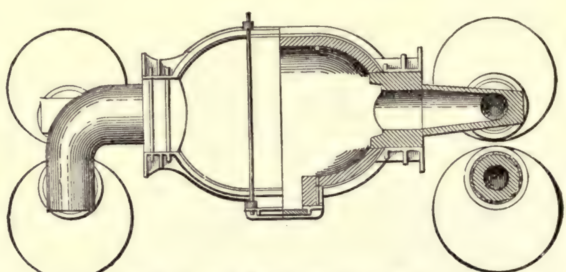


FIG. 6.—The Batho Furnace. Plan.

the gas entrance, the air port having a very steep pitch into the furnace of at least 8 in. in every foot. This arrangement guides the flame downward right on the hearth, and does away with much of the sharp cutting action of the flame on the roof, which thus has to stand the reflected and radiated heat only. The basic lining is separated from the acid by $\frac{1}{4}$ to $\frac{1}{2}$ in. only of neutral material in the form of carbon brick or chrome ore. The upper 18 in. of the lining walls of the melting chamber are of silica brick. The Batho furnace is well adapted for the basic process on account of the facility of getting at and replacing the linings. (See "Recent Improvements in Open-hearth Steel Furnaces," by A. E. Hunt, Trans. Am. Inst. Mining Engrs., Vol. XVI.)

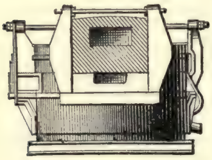


FIG. 7.—End elevation.

Open-hearth Practice in Europe.—Mr. F. Lynwood Garrison, in his report on

the metallurgical arts, at the Paris Exhibition (*Journal of Franklin Institute,* 1890), says :

Since the time of the introduction by Messrs. Martin of the new process in the Sireuil works, the size of the open-hearth furnace has always been increasing. Instead of the 3 to 4-ton furnaces first used, 10-ton furnaces, 20-ton furnaces, and even, as in some steel works of the Loire district, 35-ton furnaces can now be found.

In reference to the manner of constructing the furnace, the majority are of the fixed type, the so-called Siemens-Martin furnace, designed at first by the Messrs. Martin themselves, and having regenerators situated underneath the hearth, and the reversing valves on one of the small sides. In two or three steel works only can the Pernot furnaces be found, with a revolving circular basin or hollow hearth, or the Batho furnace, with a round hearth, supported by an iron plate, free underneath, and with round regenerators with plate-iron casing placed laterally and above ground.

The mode of working is usually the "scrap process." What is known as the "ore process" does not appear to be used in France. The combined use of scrap and ore, known as the "Landore process," is used only at the Alleyard Works. Professor Jordan states that the nature of the lining varies in the different works, and according to the description of materials used. Sometimes the lining is acid; that is, it is made with sand, ganister, or siliceous puddle; sometimes it is basic—that is, made with magnesia bricks or puddle (according to the system patented in 1869 by Mr. Emile Muller), or with dolomitic bricks and blocks; at other times the lining is neutral; that is, made with chrome ore (according to the Valton-Remaury process). When the lining is made with chrome ore, Messrs. Valton and Remaury state that no material is taken from the lining either by the molten metal or by the slag, so that no corrosion takes place, and it becomes possible to act on the metal either by scraps or by ores, or by various agents in such a manner as to effect a complete dephosphorization, and to produce various descriptions of steel.

Use of Aluminum to secure Sound Ingots.—It has been found that the addition of a small quantity of aluminum to molten steel just before pouring into ingots has a beneficial effect in rendering the ingots sound. Mr. J. W. Langley, of Pittsburg, in a paper read at the meeting of the American Institute of Mining Engineers in 1891, says :

The practice in pouring ingots is as follows : The aluminum, in small pieces of a quarter or half-pound weight, is thrown into the ladle during the tapping, shortly after a small quantity of steel has already entered it. The aluminum melts almost instantaneously, and diffuses with great rapidity throughout the contents of the ladle. The diffusion seems to be complete, for the writer has never seen the slightest action indicating want of homogeneity of mixture—all of the ingots poured from one ladle being precisely alike so far as the specific action of the aluminum was concerned. The quantity of aluminum to be employed will vary slightly according to the kind of steel and the results to be attained. For open-hearth steel, containing less than 0.50 per cent. carbon, the amount will range from 5 to 10 ounces per ton of steel. For Bessemer steel the quantities should be slightly increased, viz.: 7 to 16 ounces. For steel containing over 0.50 per cent. carbon, aluminum should be used cautiously; in general, between 4 and 8 ounces to the ton. Mr. George G. McMurtrie, president of the Apollo Iron and Steel Co., has found that aluminum can be made to replace manganese, and has rolled ingots down to thin sheets by using one half-pound of aluminum per ton of steel.

The Hoerde Desulphurizing Process.—Mr. J. Massenez, of Hoerde, Germany, read a paper at the London meeting of the Iron and Steel Institute, in 1891, describing a process adopted at his works of desulphurizing molten pig iron prior to its conversion into steel by the Bessemer process. We extract from this paper as follows :

In the treatment of phosphoric pig iron, which is employed in the production of basic steel, it is not sufficient merely to conduct the molten pig iron in large quantities to the converter in a mixed condition ; but the problem here is to render the proportion of sulphur also independent of the blast furnace process to such an extent that the proportion of sulphur in the finished steel is so low that the quality of the steel is in no way influenced by it. In order to effect satisfactory desulphurization attention has been bestowed on the fact that iron sulphide is converted by manganese into manganese sulphide and iron. If sulphureted pig iron, poor in manganese, is added in a fluid condition to manganiferous molten pig iron, poor in sulphur, the metal is desulphurized and a manganese sulphide slag is formed. At Hoerde, the mixing and desulphurizing apparatus holds 70 tons of pig iron and has the shape of a converter, moved by hydraulic machinery. An hydraulic pressure of 8 atmospheres is sufficient to set it in motion. The vessel is provided with a double lining of fire bricks of the same quality as those used for the lining of blast furnaces. This lining is attacked only along the slag line, and does not require repair until it has been in use for some six weeks. The consumption of manganese is very low. Theoretically it is the quantity required for the formation of manganese sulphide, and in practice it has been found that this amounts to about 0.2 per cent. The proportion of manganese which the desulphurized pig iron coming from the vessel should contain is best kept at about 1.5 per cent. in order to render the desulphurization as complete as possible. It has been found that if highly sulphureted pig iron is poured from the blast furnace into the desulphurizing vessel, 15 to 20 minutes are sufficient to effect the desulphurization requisite for the steel process. The iron in the vessel remains sufficiently fluid for several hours. It has been found quite unnecessary to obtain heat by passing and burning a current of gas above the bath of metal. Daily analyses during a month at Hoerde of the desulphurized metal for the basic process gave

results as follows: phosphorus ranging from 2·62 to 2·93 per cent. Manganese, 1·15 to 2·97 per cent.; silicon, 0·11 to 0·31; sulphur, 0·035 to 0·086, the percentage of sulphur before desulphurization being 0·100 to 0·481.

The Robert-Bessemer Converter, Fig. 8, is described in F. Lynwood Garrison's report on the Metallurgical Arts at the Paris Exhibition (*Journal Franklin Institute*, 1890), which see.

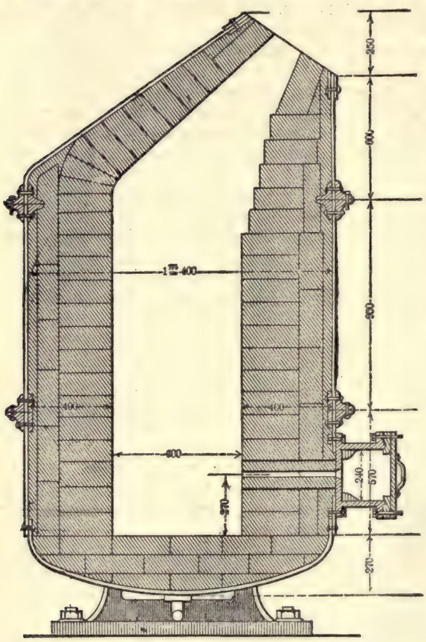


FIG. 8.—The Robert-Bessemer Converter.

What is claimed as novel in the converter is "a combination of several parts in a converter having a flat side, in which flat side are ranged the tuyeres in a plane horizontal to the axis of the converter, and all in the same plane." "The tuyeres having an inclination to enable a rotary motion to be imparted to the metal bath, and being so disposed that by tilting the converter in the trunnions the depth of the metal over the tuyeres can be regulated."

It seems to have produced excellent results wherever put in operation and to be the only side-blown converter which is suitable for the basic process, as the large amount of slag produced would soon choke up a similar fixed converter.

Processes for preventing Piping of Steel Ingots.—Recent processes for preventing piping are thus described by Mr. T. S. Crane, in a paper published in the Trans. A. S. M. E., Vol. X. Strenuous efforts have been made, and by many different modes, to prevent the piping of cast-steel ingots, but it is only recently that a simple apparatus has been perfected for practically accomplishing this object.

Some of the most modern means heretofore used are mentioned below. The "Sweet" process consists in putting powdered charcoal upon the top of the ingot when poured, to prevent its upper end from oxidation, and, by its combustion, to maintain the fluidity of the steel, and thus assist in filling the pipe as it forms. The entire effect is very slight. The compression process used by Whitworth to form sound steel ingots has never been wholly successful, as it operated to consolidate the exterior of the casting without permitting the free discharge of the gases from its interior; and while it has operated to prevent the formation of a pipe or local depression, it has been liable to produce a spongy or porous casting. Various modifications of Whitworth's plan have been devised. S. T. Williams has devised a compression process for making sound circular ingots for saw plates. The comparatively thin and flat form of such ingots permits the sides to be bent or crushed inward, while the interior of the ingot is still at a welding heat, and this effects the desired purpose much better than in a square ingot, where the compression of the sides would tend to induce cracks, as the metal, when first crystallized, is not very tenacious. In experiments tried by William R. Hinsdale, at the Jersey City Steel Works, in the year 1884, it was found that a pressure of 300 lbs. per sq. in., operating upon a 24-in. piston, and concentrated upon the end of a 3½-in.-square ingot, merely produced an ingot containing innumerable globules of gas.

The "Billings and Hinsdale" process provided a reservoir at the top of the mold, and a movable plunger within the mold, by which the steel was drawn downward to make an ingot, which would be fed during the shrinkage period by the residue remaining in the reservoir. This process is not, therefore, convenient except for the casting of large ingots. Mr. Hinsdale also experimented at the Jersey City Steel Works with a pressure of 60,000 lbs. per sq. in. upon the metal. The result was the shortening of the ingot from 25 to 22 in. in length, and perfect solidity, except that the pipe appeared in the same form, a flaw, as it ordinarily displays itself at the piped end of a forged bar. Mr. Hinsdale thus found that piping, or its effects, could not be eliminated by pressure, and invented a perforated plug to insert in the mold upon the top of the fluid metal, through the perforation in which the gases might escape while applying the pressure.

With this device the top of the ingot became slightly chilled, and a crust formed thereon; but after the pressure upon the metal was raised to about 20,000 lbs. per sq. in., the crust of metal exploded with a loud report, and a circular piece like a boiler punching shot out of the perforation in the plunger, followed by all the gases, and sufficient metal to fill the cavity and form a stud as long as one's little finger, on top of the ingot.

This process produced ingots absolutely solid and free from defect, which had been proved impossible by the mere use of pressure. The expense of all these methods, and the inconvenience of applying them to the open ingot molds universally used for casting steel ingots, resulted in the invention by Mr. J. B. D'A. Boulton, of Jersey City, N. J., of an apparatus in which ingot molds made without bottom, but in other respects like the common ingot molds,

are superposed, one upon another, and successively filled, the shrinkage in each ingot being fed by the fluid metal in that above it, and the resulting product being a series of absolutely sound ingots connected by cold-shut joints. An ingot made by this process, and split open,

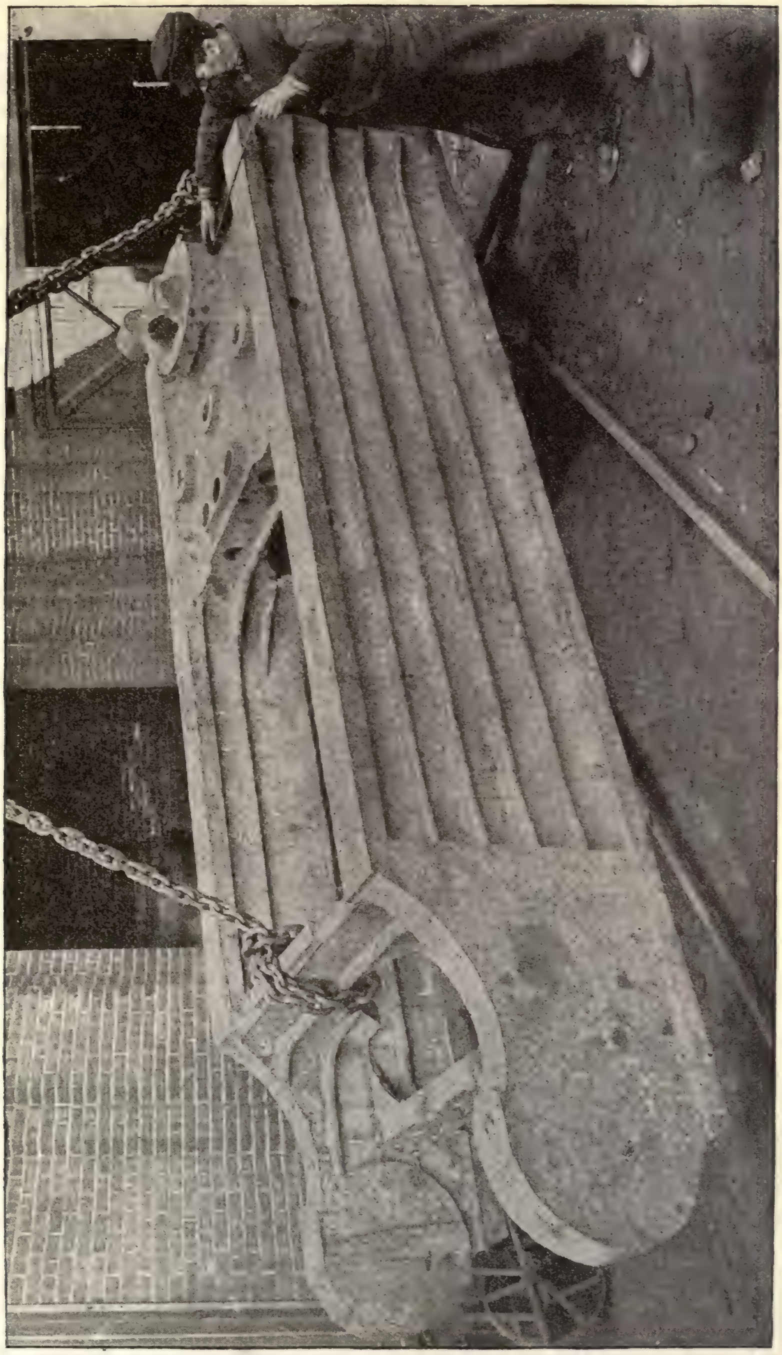


Fig. 9.—Steel casting, U. S. S. Puritan turret mount.

has been shown to be perfectly sound. By interposing an asbestos washer with a small aperture between the successive mold sections, the resulting product was necked at intervals, so that the ingot bar could be readily broken at such points. Boulton's apparatus has been in commercial operation at the West Bergen Steel Works of Messrs. Spaulding & Jennings,

since December, 1887, and one ingot per minute is cast in it regularly when the heat is ready. The ingots cast are nearly 4 in. square, and are absolutely sound ; but the machine is equally adapted to cast larger ingots by making the holder and the ingot molds of suitable dimensions. One man suffices to operate the levers of the hydraulic apparatus, and the ordinary operators are employed to pour the metal.

Mr. William R. Hinsdale obtained a United States patent, dated January 6, 1891, No. 444,-381, for a process of forming ingots, which he states consists, essentially, in chilling the surface of the ingot which is last cast in the mold, and which is therefore the hottest, and in reversing the ingot after such surface is sufficiently chilled to exclude the atmosphere from the fluid interior of the ingot.

In this invention the retention of the fluid metal within the chilled shell is absolutely essential, whereas in earlier methods the discharge of the fluid metal is the ultimate object, and the chilling of the top end of the casting before reversing the ingot is carefully avoided. One of the claims of the patent is as follows : The process of forming ingots, which consists, first, in inserting a cup of heated material in the bottom of the mold ; secondly, filling the mold ; thirdly, excluding the atmosphere from the mouth of the mold ; and, fourthly, reversing the mold, as and for the purpose set forth.

Steel Castings.—Fig. 9 is taken from a photograph of a box-slide casting made by the Medvale Steel Co., of Nicetown, Pa., for the 12-in. turret mount for the United States turret ship *Puritan*, in October, 1891. The government specifications under which this casting was made are as follow : Tensile strength, 65,000 lbs. per sq. in.; elastic limit, 25,000 lbs. per sq. in.; extension, 15 per cent.; contraction, 25 per cent. The result of the tests made from this casting showed that the steel possessed the following physical characteristics : Tensile strength, 65,174 lbs. per sq. in.; elastic limit, 31,058 lbs. per sq. in.; extension, 25.10 per cent.; contraction, 35·04 per cent. The weight of the casting was 15,547 lbs.

In addition to the tests above given on the sheet enclosed, the casting was put to a ballistic test, to determine the ductility of the metal. This test is made by subjecting the pieces to the fire of rapid-firing guns at short range, and the castings are accepted if it is shown by this test that they can be bent or perforated by projectiles fired from these guns without breaking. Ordinary steel castings, if put to this test, are apt to fly to pieces at the first discharge, thus making the gun sought to be shielded useless, and probably causing much loss of life. The combination of high elastic limit, extension, and contraction in the casting illustrated, indicates that it would withstand an immense amount of battering without going to pieces, and that it is particularly well suited for the purpose intended. What is chiefly remarkable about this casting is, that while the tensile strength developed is but 174 lbs. above the government requirements, the manufacturers succeeded in increasing the elastic limit by 24·2 per cent., the extension by 67 per cent., and the contraction by 40 per cent. beyond the requirements. That this was not an accidental performance was shown by the fact that subsequent castings from the same pattern have shown in the average fully as good results.

Stem, Cotton Picking : see Harvester, Cotton.

Step : see Water-wheels.

STOKERS, MECHANICAL. *The Roney Mechanical Stoker*, Figs. 1, 2, and 3, when

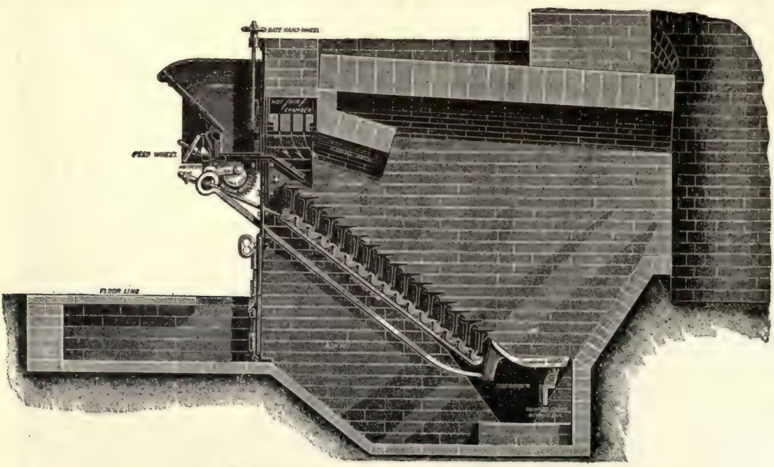


FIG. 1.—The Roney mechanical stoker.

attached to steam boilers, receives the fuel in bulk, and feeds it continuously and at any desired rate to the furnace.

The fuel to be burned is dumped into the hopper on the boiler front. In small plants it may be shoveled in by hand. In large plants it is usually handled direct from the car to the hopper by elevators and conveyors. Set in the lower part of the hopper is a pusher, to which

is attached by a flexible connection the feed plate forming the bottom of the hopper. The pusher, by a vibratory motion, carrying with it the feed plate, gradually forces the fuel on to the grates over the dead plate. These grates consist of horizontal flat-surfaced bars running from side to side of the furnace, carried on inclined side-bearers extending from the throat of the hopper to the rear and bottom of the ash pit. The grates, therefore, in their normal condition form a series of steps, on to the top step of which coal is fed from the dead plate. These steps at the inclination given would, however, prevent the free descent of the coal. But each bar rests in a concave seat in the bearer, and is capable of a rocking motion through an adjustable angle. All the grate bars are coupled together by a rocker bar, the notches of which engage with a lug on the lower rib of each grate bar, pin connections being made with two of the grate bars only, for the purpose of holding the rocker bar in position. A variable back-and-forth motion being given to the rocker bar, through a connecting rod, the grate bars necessarily rock in unison, now forming a series of steps, and now approximating to an inclined plane, with the grates partly overlapping, like the shingles on a roof. Assuming the grates to be covered by a bed of coal, and fresh fuel being fed in at the top, it is obvious that when the grates rock forward the fire will tend to work down in a body. But before the coal can move too far, the bars rock back to the stepped position, checking the downward motion, breaking up the cake thoroughly over the whole surface, and admitting a free volume of air through the fire. The rocking motion is slow, being from seven to ten strokes per minute, according to the grade of the coal. This alternate starting and checking motion being continuous, keeps the fire constantly stirred and broken up from underneath, and finally lands the cinder and ash on the dumping grate below. By releasing the dumping rod, the dumping grate tilts forward, throwing the cinder into the ash pit, after which it is again closed ready for further operation. The dumping grate is made in two parts, so that each half can

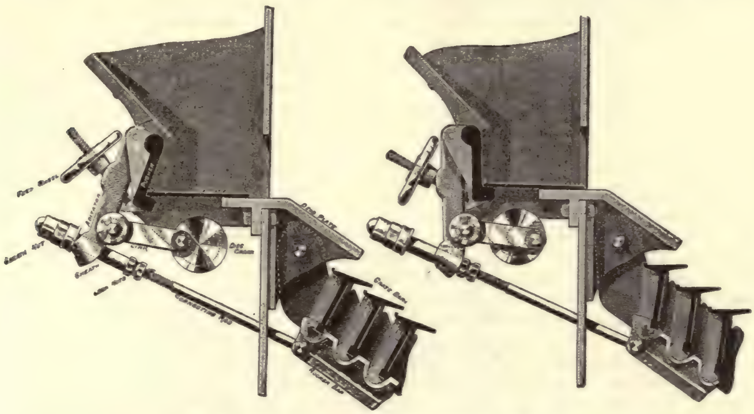


FIG. 2.—The Roney mechanical stoker. FIG. 3.

be dumped separately. The operation of the stoker, therefore, consists of a slow but continuous feed, a constant stirring of the fire, and an automatic rejection of the cinder, all performed without opening the fire doors.

All motion is taken from one driving shaft. In a single stoker this shaft may either be driven through a worm gear from a small engine attached to the boiler front and consuming a hardly measurable fraction of a horse-power, or it may be driven by a link belt from any convenient point of the nearest shaft. In large batteries of boilers the driving shaft is extended across all the boiler fronts, delivering power to each stoker, and, with the elevators and conveyors, is driven by a small independent engine. The largest stoker can easily be turned over by hand, indicating the nominal power consumed. The worm gear shaft carries a disk and wrist-pin, from which a link couples to the agitator. Through the eye of the agitator passes a stud, screwed into the pusher, on which stud is a feed wheel by which the stroke of the pusher, and, consequently, the amount of feed, is regulated. The agitator having a fixed stroke, it is apparent that if the feed wheel is run down against it in the position shown in the engraving, the pusher will be given its full traverse and the greatest feed. If run back to clear the travel of the agitator, the pusher will, of course, have no motion and the feed will stop. Between these extremes any desired rate of feed can be given.

In like manner, the rock of the grate bars can be adjusted between any limiting angles, and over a range of motion from no movement to full throw, by means of the sheath nut and jam nuts on the connecting rod. By these adjustments the whole action of the stoker is controlled, and the fires forced, checked, or banked at will.

Stone Breaker : see Ore-crushing Machines.

STORAGE BATTERIES. The storage, secondary or reversible battery, and accumulator are different terms applied to a form of cell based on the principle demonstrated by Faraday in 1834, that chemical and electrical energy were mutually convertible. In 1859,

after experiments with various metals, Planté decided upon the use of lead plates in dilute sulphuric acid, because in discharge both plates were active; that is, not only did the peroxide of lead plate combine with hydrogen, but the reduced metallic lead combined with oxygen. *Planté's cell* was originally constructed with two plates of sheet lead, separated by gutta-percha strips, one sheet being laid over the other, with two gutta-percha strips between them, and two more laid on the upper sheet, as shown at *A*, Fig. 1.

They were then rolled together and clamped, as shown at *B*, a strip of lead being left attached to the corner of each sheet in cutting, by which connection could be made. The sheets thus rolled together were placed in a jar of glass or ebonite, containing a 10 per cent. solution of sulphuric acid. The jar had an ebonite cover, with binding screws to which the connecting strips were attached; also clamps for holding wires to show the heating effect of the discharge.

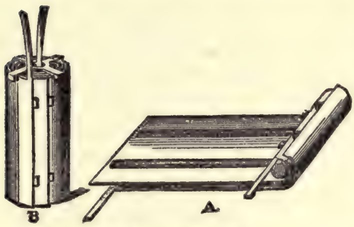


FIG. 1.—Planté's cell.

The electrical preparation of the plates was accomplished by charging them with a battery of two or more cells, one cell being insufficient to overcome the resistance from polarization. The current was continued till the oxygen evolved at the positive pole ceased to combine with the lead and was given off as gas. The cell was then disconnected from the battery, and discharged by making connection between its electrodes, and a fresh charge given in reverse order, and continued as before until gas was given off. This process was continued for several months, with intervening periods of repose, during which the cell remained charged, and the time of charging was increased from a few minutes on the first day to several hours subsequently. In like manner, the periods of repose were increased from hours to weeks and months. Three distinct periods are thus required in this process: that of charging, of repose, and of discharging, during each of which a distinct chemical reaction occurs. During the charging, peroxide of lead collects on the plate connected with the + pole, and hydrogen on the one connected with the − pole. At first only a thin film of the peroxide is formed and a small amount of hydrogen collected. The plates are then discharged, and during the discharge the peroxide, which is insoluble in sulphuric acid, is reduced to monoxide, PbO, which is immediately reduced to sulphate of lead $PbSO_4$, by the acid present in the solution, while the oxygen atom taken from the peroxide unites with the lead on the opposite plate, forming monoxide, which, in turn, is reduced to sulphate, the result being a thin film of sulphate on each plate. The plates are then charged in reverse order, and the sulphate on the plate, now connected with the + pole, is reduced by the oxygen to peroxide, while that on the opposite plate is reduced by the hydrogen to spongy lead, which adheres to the plate in a finely divided condition. As each subsequent charge, after discharge and reversal, produces the same result, each coating continues to increase in thickness, and the spongy lead affording increased facility for the formation of the peroxide, the chemical reaction proceeds more rapidly. The increased thickness of the peroxide soon interposes a strong resistance to this reaction; hence a period of repose previous to the discharge becomes necessary, and during this period, local action, as it is called, takes place. This consists in the reduction of the peroxide to sulphate from the reaction of the supporting lead plate. The metallic lead having a strong affinity for oxygen, the peroxide parts with the atom of its oxygen which unites with the lead, and the resulting monoxide is immediately reduced to sulphate by the acid. The result of the chemical reaction of the discharge having formed sulphate of lead on both plates, this sulphate lying next to the plates forms a resistance which impedes local action which takes place during the period of repose. The peroxide being limited in quantity and in close contact with the spongy lead, is rapidly reduced to sulphate, while the original peroxide coating on the other plate, from its greater thickness and the resistance of an excess of sulphate, is reduced much more slowly. These various chemical reactions result in an increased thickness of the peroxide deposit with each charge, while an increased thickness of spongy lead remains on the opposite plate after each reversal; and when the process has been continued long enough to produce a sufficient thickness of each coating for a practically serviceable cell, the alternate charging and discharging with reversal is discontinued, and the cell being ready for use, it is always thereafter charged in the same direction. When the cell is put into practical use, these chemical reactions continue the same as during the forming process, sulphate being reduced to peroxide by each charge, and peroxide to sulphate by each discharge; and the electric energy varies as to reaction, and ceases when the chemical affinities are satisfied. In the storage cell the electric energy must first be supplied from an external source, and the action, both chemical and electrical, is limited, dependent on the amount of electrical charge given.

Faure's Secondary Battery.—Camille A. Faure, a French chemist, constructed a cell based on Planté's about 1880. But he substituted mechanically prepared plates for those prepared by electricity, by coating their surfaces with a paste of red lead (minium, Pb_3O_4) and sulphuric acid, which, when subjected to electrical action, was rapidly reduced to peroxide on the one plate and spongy lead on the other. After this was applied it was coated with paper, and each plate then enveloped in felt to retain the coating on the surface and to insulate the plates from each other. They were then rolled together and placed in the acidulated water in the cell, and subjected to electric action with reversals, and in a few days the cell was ready for use. The great advantage of the Faure over the Planté cell consists

in the rapid reduction of the minium instead of the slow reduction of the metallic lead. It soon developed serious faults, however; but the rapid preparation of the plates was so great an advance that various inventors worked patiently to overcome the faults which had developed. The various improvements of Swan, Sellon, Volckmar, Shaw, and others resulted in producing the improved cell shown in Fig. 2.

This is made of different sizes and a variable number of plates, according to the purpose for which it is intended. The standard type shown, made by the Accumulator Co., of New York, called the 15A cell, has 15 plates, 7 positives and 8 negatives, those plates being called positive which are connected with the positive pole in charging, and from which the external current flows in discharging; the others being known as negative. Each positive plate is $9\frac{1}{8}$ in. high, $8\frac{1}{2}$ in. wide, and $\frac{1}{4}$ in. thick; and each negative, $9\frac{7}{8}$ in. high, $9\frac{1}{2}$ in. wide, and $\frac{3}{16}$ in. thick. They are of lead cast in the form of grids, with square openings to hold the paste, as shown at *A*, Fig. 3, this form being the invention of Swan.

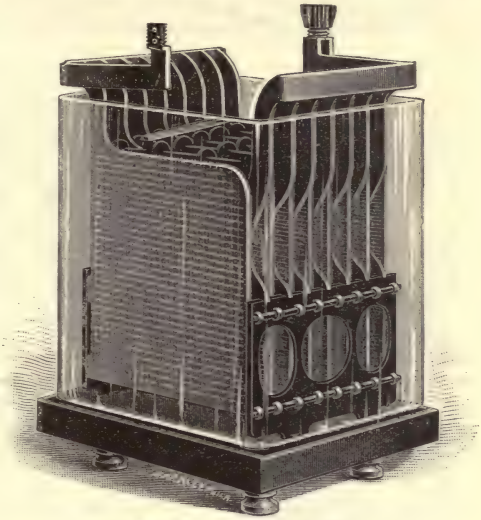
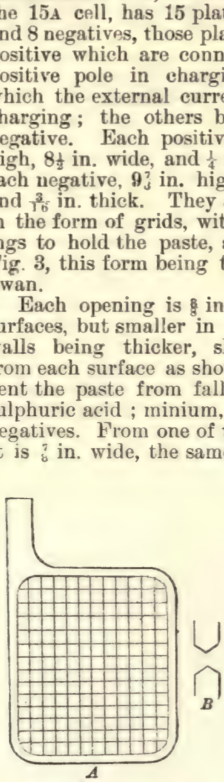


Fig. 2.—Accumulator cell.

Each opening is $\frac{5}{8}$ in. square at the surfaces, but smaller in the center, the walls being thicker, sloping inward from each surface as shown in cross section at *B*, Fig. 4, an improvement by Sellon to prevent the paste from falling out. These openings are filled with the paste of lead oxide and sulphuric acid; minium, Pb_3O_4, being used for the positive plates, and litharge, PbO, for the negatives. From one of the upper corners of each plate a lead bar extends as shown in Fig. 3. It is $\frac{7}{8}$ in. wide, the same thickness as the plate, and extends $2\frac{5}{8}$ in. above the highest plates. These vertical bars on each set of plates are attached to a horizontal bar of the same width, as shown in Fig. 2, connecting the set of plates together and keeping them a given distance apart, the space between each two positives being $\frac{9}{16}$ of an in. and that between each two negatives $\frac{5}{8}$ in., each set with its bars being a single casting. The horizontal bars are extended and the ends turned in for convenience, forming lugs for connecting the cells into a battery (see Fig. 2). When the plates are ready to be set up, the 7 positives are passed in between the 8 negatives, so that they alternate, each positive being between two negatives with a $\frac{3}{16}$ in. space between them. In Fig. 2, the positives are shown with their bars to the right and the negatives with their bars to the left. As the outside plates are negatives and the outside surfaces inactive, the same number of active surfaces, positive and negative, 14 in each set, are adjacent to each other within. In each negative plate a number of openings are left without paste, into which are drawn plugs of soft rubber, which project $\frac{3}{16}$ in. on each side, resting against the positives and holding the plates that distance apart. Two plates of glass of the same size as the lead plates are placed outside, one on each side, against the projecting rubber plugs, to keep them from being pressed out, and all the plates are bound together and held in position by strong rubber bands. They are then placed in a glass jar 11 in. long, $8\frac{1}{2}$ in. wide, and 13 in. high outside, and rest on two strips of wood placed in the bottom to allow free circulation of the fluid The average E.M.F. of this cell is about 2 volts, its internal resistance .005 ohm, and its capacity 350 ampere hours, its best working rate being 35 amperes for 10 hours. The cell weighs 125 lbs., which can be reduced by using $\frac{1}{8}$ in. and $\frac{3}{32}$ in. plates, but it is not so durable. The *Julien Accumulator* is the invention of Edmond Julien, of Belgium. Its general principles are essentially the same as have been already described, but his specific claim is that the grids are made of a special alloy which prevents oxidation and buckling, and consequently gives greater durability. The composition is said to consist of 94·5 lead, 4·2 antimony, and 1·3 mercury.



Figs. 3 and 4.—Plate.

Drake and Gorham's cell has plates formed of roughened strips of lead laid horizontally one over the other, and connected by their ends to upright rods. From its construction this plate is free to expand and contract without injury to itself. *Niblett's* so-called "solid cell" has its electrodes separated by porous partitions.

Improvements of the Faure type are, generally: (1) Those which have for their object the retention of the paste on the plate; and, (2) those intended to provide better connection between the support and the active material.

For the retention of the paste, instead of perforations, grooves or recesses have been made on the surface, or the plate is cast with projections from it so as to afford a lodgment for the active material. The *Tudor plate* (*see below*) is an instance of this type.

The construction of a mold to produce a perforation expanding inwardly is a difficult matter, and therefore the grids are cast in two halves and subsequently joined, as in the

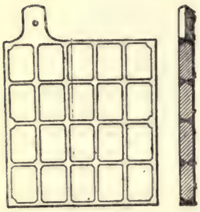


FIG. 5.—Gadot cell.

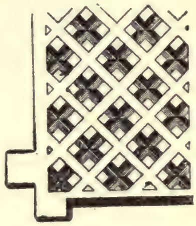


FIG. 6 —Correns cell.

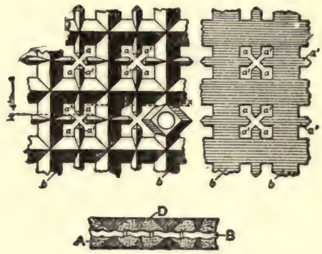


FIG. 7.—Roberts cell.

Gadot cell, Fig. 5. In the *Correns* cell, Fig. 6, much used in Germany, the grid has the form of a double lattice. In the *Roberts* cell, Fig. 7, two grids are used, pasted on the side and then united to form a plate with the paste inside.

The *Tommasi multitubular* storage battery (Fig. 8), invented by Dr. Donato Tommasi, of Paris, has each electrode formed of a perforated tube, or folded sheet, closed at one end by a small plate of insulating material, into which is screwed a rod. The rod, which serves as a support for the tube electrode, is provided with a suspension head, which also serves as a contact. Instead of cylindrical tubes, prismatic ones may be employed, as in Fig. 8, utilizing the space to better advantage. In the annular space between the tube and the contact conductor of each electrode the active material, spongy lead, or lead oxide, etc., is packed, so that the tube serves only as a support for such matter, and can be made of any substance desired, so long as it is not attacked by the acid.

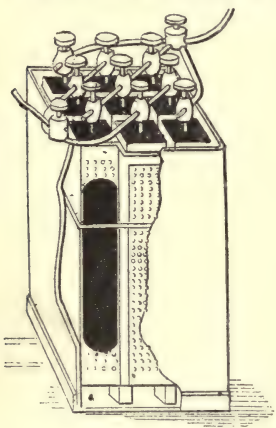


FIG. 8.—Tommasi multitubular cell.

Reynier's high voltage elastic accumulator was designed to afford a single compact structure, having the qualities of high voltage, solidity, and portability. As shown in Fig. 9, it has sixteen plates mounted in flexible pockets. These elements are placed flat one against the other, and compressed between two end plates of wood by means of rubber bands. A bridge consisting of hard wood impregnated with a waterproofing material carries the whole, which may be suspended, or rest upon its base, as desired. This arrangement gives to the active solid matter an artificial elasticity which results in large specific power and storing capacity. This continuous compression of the plates, etc., gives protection against rough handling.

The *Desmazures* storage battery (France) has its electrodes composed of amalgamated zinc plates and porous copper plates, the latter being produced by the consolidation of powdered copper under very great pressure. The zinc plates form the negative electrode and are in metallic connection with the box, which is also of zinc, while the positive plates are placed in vegetable parchment bags and suspended in the usual way. Contact with the negative plates is prevented by glass rods. The electrolyte is a mixture of chloride of sodium and a caustic solution of zinc oxide.

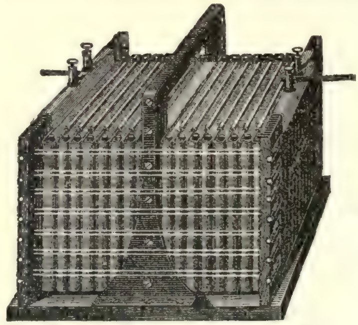


FIG. 9.—Reynier's accumulator.

The *Tamine* accumulator (Brussels) is of the Planté type, in which the liquid consists of a saturated sulphate of zinc solution, to which is added 50 per cent. sulphuric acid, 5 per cent. of sulphate of ammonia, and 5 per cent. of sulphate of mercury. In making up the cell, the ingredients are poured in in the reverse order to that given here. The addition of the sulphates of mercury and ammonia is said to prevent the formation of sulphate of lead on an open circuit. The E. M. F. of the cell is given as 2·3 volts.

The use of *Lithanode* as an active material in the anodes of storage batteries has been advocated by Desmond G. Fitz-Gerald. This substance is peroxide of lead in a dense, coherent, and highly conductive form, and is obtained by a patented process. Its chemical

composition is almost identical with the active material generally used, but it is different in molecular construction, and free from liability to local action.

A. V. Meserole, of New York City, has found that an electrolytic sponge composed largely of mercury and zinc with some lead, in combination with a plate of peroxidized lead, produces a very efficient storage battery. By using the same material differently combined and formed, radically different results are obtained.

In the *Peyrusson* storage battery (France) the lead support is composed of a central rod, and a number of longitudinal and radial strips, which are placed in a porous cup. The spaces between the strips are then filled with peroxide of lead and other material capable of producing the same by oxidation, which is mixed with a little acidulated water. Other forms may be substituted for the radial strips. The porous cup is placed in a second vessel of glass, containing the electrode of the negative pole.

In the storage battery of *Anthony Reckenzaun* (London) the active material is completely formed in advance of its application, and is so held in place that the expansion of the plate has no effect on the adhesive property of the active material. Small cylinders of peroxide of lead are prepared, and placed at short distances from each other in regular lines upon the lower half of the corrugated mold. The two halves being fitted together, the molten metal is poured in, forming a composite plate. As shown in Fig. 10, these cylinders are exposed for a large part of their surface to the direct action of the electrolyte, being held only at the top. But the inclosing metal is sufficient to permit the plate to be bent over into a complete circle, without causing the small cylinders to fall out. The plates are designed specially for street car and similar work, where rough treatment is unavoidable.

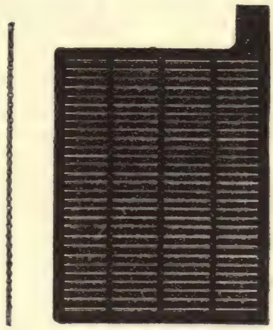


Fig. 10.—Plate.

The *Gibson* storage battery (New York) has the peroxide of lead introduced in capsules which are perforated, to allow the air to pass out when they are being filled, and also to permit the entrance of the electrolyte when the plate is immersed. The capsules when inserted in the holes of the plate fit loosely, and project beyond the surface. The plate is then rolled, and the pressure "upsets" the capsules and compresses them against the adjacent metal. A recent form of this battery has the plates arranged horizontally instead of vertically, as is usually the case (Fig. 11). The plates are strung on bolts, and have distance pieces between them to keep the plates apart and prevent short circuiting.

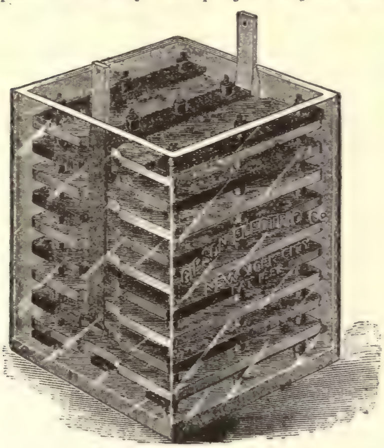


Fig. 11.—Gibson battery.

Waddell and Entz (New York) have made numerous experiments for adapting copper oxide for use in the storage battery. They employ for this purpose a tube of woven copper wire, as shown in Fig. 12. To avoid the lack of coherence in pure copper oxide, *Messrs. Entz and Phillips* have modified the composition by combining with the oxide of copper a small portion of sulphur, and then heating the mixture. The sulphur is thoroughly mixed with the oxide and then applied to the woven copper wire. The whole is then heated to burn off the sulphur, but in so doing the oxygen of the copper is absorbed to form the SO_2, leaving the oxide in a reduced state on the support. The heating then being continued, the exposed portions of the particles of the mass are reoxidized, while the unexposed portions at the juncture, being protected from the air, remain metallic and serve to hold the mass together. The sulphur, when used in this manner, therefore, acts as a binding, toughening, or hardening agent, without being actually present in the mass after the treatment.

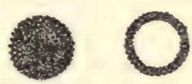


Fig. 12.—Tube.

The Laurent-Cely accumulator is distinctive in the special nature of the lead paste employed, and in the manner in which it is applied to the plates. The active element is a mixture of chloride of lead and chloride of zinc. The fused chloride of lead has a density of 5·6; by incorporating chloride of zinc with it in certain proportions the density is reduced to 4.5. This mixture, brought to a state of fusion, is run into cast-iron molds in the form of small buttons, with rounded edges. After cooling, the buttons are washed to remove the chloride of zinc, and to thus render them somewhat porous. Their density then varies from 4·2 to 3·4. The buttons which serve for the manufacture of the negative plates are then arranged in a metallic mold, into which antimonial lead is run; this surrounds the buttons with a frame which holds them fixed in their positions. The negative plates are mounted in cells filled with acidulated water and provided with zinc electrodes. The composite and zinc

plates are then short circuited. The hydrogen which is disengaged upon the positive electrode reduces the chloride of lead, and there are thus obtained buttons of spongy lead of a density between 2·5 and 3·1, while that of ordinary lead is 11·35. The buttons used in the manufacture of the positive plates are first transformed into spongy lead, then heated in the air to oxidize them, and transformed into spongy litharge. They are fixed, like the negative buttons, in a frame of antimonial lead.

In the *Tudor cell*, Fig. 13, the positive plates are first treated by Planté's process, coating them with a layer of crystalline electrolytic peroxide ; the grooves are then partially filled with a paste of peroxide of lead, and pressure is applied to the ridges to expand them and partially close the mouths of the grooves.

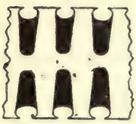


FIG. 13.—Tudor cell.

Besides the improvements in the plates, various devices have been resorted to with the view of decreasing the resistance of the lugs and securing better contact between plates of the same sign, such as making connection by tinned copper rods passed through holes in the lugs. Lead is afterwards cast around the copper so that it is screened from the action of the acid.

Dr. Paul Schoop, of Switzerland, has produced a successful gelatinous electrolyte, by adding one volume of dilute sodium silicate (water glass), density 1·18, to two volumes of dilute sulphuric acid of 1·250 density. To prevent short circuiting between the plates by the material dislodged in working, they are now either slung or rested on supports which are so placed that the formation of a layer of mud between them is prevented. See Fig. 14.

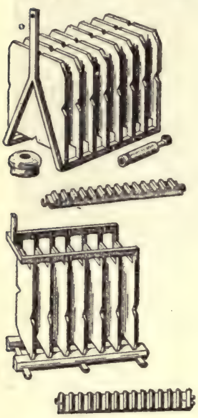


FIG. 14.—Schoop plate and holder.

Inactive material is sometimes packed between the plates to prevent short circuiting and to retain the active material. In England Barber-Starkey has tried filling in between the plates with a mixture of plaster of Paris and sawdust ; Fuller used porous pots ; and in the United States, in the Pumpelly battery, cellulose, or wood pulp, is used to separate the plates, which are arranged horizontally.

In the *Atlas cell,* Fig. 15, constructed by Carl Hering, the plates consist of blocks made of oxides and salts of lead.

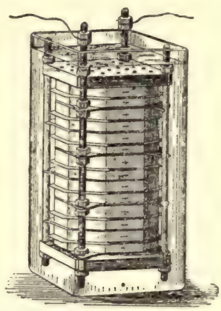


FIG. 15.—Atlas cell.

The use of storage batteries in central station work has begun to assume large proportions. In a recent work on Continental central stations, Mr. Killingworth Hedges gives a list of stations in which batteries are a valuable adjunct. Most of the plants are small, but some of them are of quite respectable size. They run as follows : Barmen, 5,000 lamps of 16-candle power ; Hanover, 30,000 ; Düsseldorf, 20,000 ; Dessau, 2,500 ; Rheims, 540 ; Berlin, 800 ; Bad Kösen, 600 ; Gevelsberg, 2,000 ; Bamberg, 2,700 ; Darmstadt, 5,800 ; Paris, 19,500 ; Gablonz, 1,500 ; Konigsberg, 1,600 ; Blankenburg, 1,000 ; Berlin (Hospital), 2,000 ; Vienna, 10,000. To this list might be added, we believe, Salzburg, Lyons, Toulon, Montpelier, Mulhausen, Stockholm, Sundsvall, Munchen-Schwabing, Varese, Susa, Bremen, Breslau, and Stettin, although few details are given with regard to these ; while it appears that batteries are to be added to the Hamburg central station, which operates 12,000 lights ; Wildbad-Gastein, 1,200 ; Elberfeld, 14,000 ; Arco, 2,500. It is not understood from this list that the equipment of batteries is in any instance equal to the number of lamps named ; but in several cases the figures are large. Barmen, it seems, has four double sets of batteries, 68 cells each, and is now going to erect five sub-stations which will be charged during the day by the main central station. This sub-station plan has not had any trial in America, except at Cheyenne, Wyo.; Germantown, Pa., and Haverford College, Pa. At Hanover, Germany, the accumulators are placed on four floors, each battery consisting of 136 cells of 1,320 ampere hour capacity, and a discharge of 396 amperes. The Düsseldorf plant is already running three battery sub-stations ; the largest has two batteries of 140 cells, each with a discharge of 483 amperes, while the other two, with an equal number of smaller cells, discharge 248 amperes. An interesting feature of the Dessau installation is the employment of gas engines as primary power. It is stated that the addition of accumulators of 1,700 ampere hour capacity to this plant increased the investment 15 per cent. and raised the output 38 per cent. The present batteries have been in use uninterruptedly for nearly two years without attention, so it is asserted, and more than once have been called upon for an output 20 to 25 per cent. above the normal.

As to the work done in Paris, France, with storage batteries in central stations, Mr. Stanley C. C. Currie says : "The principle adopted is that of casting chloride of lead combined with a small proportion of chloride of zinc in tablets. These tablets are then placed in a special mold, and ordinary lead cast around them, thus forming a uniform plate. The plates weigh about 20 kilos (44 lbs.) each. The cells contain from 15 to 25 of these plates, making the average total weight of plates per cell about half a ton. The efficiency has averaged from 72 to 85 per cent."

The following table gives the data of the tests of different cells:

Table of Data of Secondary Batteries. (Robertson.)

Accumulator.	Type.	Material of cell Lead plates, and H_2SO_4, or otherwise.	Capacity in ampere hours.	Capacity in watt hours.	Charging current	Max. discharging current.	No. of plates. +	No. of plates. −	Thickness of plates in inches. +	Thickness of plates in inches. −	Total area of plates (sq. ft.).	Amperes per sq. ft. Total plate area. Discharge.	Approximate external dimensions of cell. Length.	Breadth.	Height.	Height over all.	Total weight of cell (lbs.).	Ampere hours per lb of total weight.	Watt hours per lb. of total weight.	Efficiency (watt). Per cent.	By whom efficiency test was made.
Reynier...	—	Lead and lead peroxide in sulphuric acid.	30	740	—	6 amps.	—	—	—	—	—	—	in. 12	in. 12	in. —	in. 12	100	0·3	7·4	—	—
E.P.S......	1888 L	Lead grids pasted.	130	247	10 to 13	13	3	4	—	—	—	—	5¼	13¼	18¼	20½	74	1·7	3·3	—	—
	1890 K	H_2SO_4 ribbed lead plates pasted. H_2SO_4	—	—	15 to 25	25	3	4	—	—	—	—	5½	11½	13½	16½	81	—	—	—	—
Oerlikon..	B	Hard lead grid plates made of red lead and litharge	50	95	6	10	4	5	0·2	0·2	1·9	5	7·8	9·2	8·77	—	39·6	1·25	2·4	—	Prof. Kohlrausch Hanover.
	E		260	494	30	48	5	6	0·2	0·2	8·9	5·4	9	14·4	16·4	—	156·2	1·6	3·1	—	
	F		160	304	18	25	5	6	0·2	0·2	5·6	4·4	9·2	11·7	12·5	—	96·8	1·6	3·1	—	Dr. Coppe, Zurich.
	D		70	133	9	9	8	9	0·1	0·1	3.8	2·3	5·5	6·8	8·6	—	26·4	2·6	5·0	—	
"D.P."...	A	Pasted positives. Lead negatives dilute H_2SO_4	140	266	12	12	—	—	—	—	—	—	13½	8	12½	—	65	2·1	4	—	—
	H		725	1,377	66	66	—	—	—	—	—	—	13½	18	12½	—	240	3	5·7	—	—
Tommasi Multi-tubular.	—	Red lead and litharge in porous pots. Dilute sulphuric acid.	321	642	25 to 100 amperes.	18 to 30	9 tubes	9 rect'ngular.	9·75 by 2 by ¾	9¾ by 2 by ¾	—	—	6¾	6¾	10½	—	Total weight of electrodes, 47·7	Per lb. of electrode, 6·7	—	80	—
Julien.....	S. 17	Pasted plates.	180	—	15	20	8	9	¼	¼	5·4	3·6	8	7	10	—	42	4·3	—	—	—
		Dilute sulphuric acid.	180	—	15	20	8	9	¼	¼	5·4	3·6	7½	5¾	9	—	37½	4·8	—	—	—
Gadot.....	1 A	Double grid containing pastilles made from oxides of lead. H_2SO_4	28	53·2	3·1 amp.	52	2	3	—	—	—	—	7	3¾	—	13·6	17·6	1·6	3	—	—
	10 E		1063	2,019·7	116	193	11	12	—	—	—	—	21·6	20·4	—	26¾	792	1·4	2·66	—	—
Crompton-Howell.	No. 11	Lead plates and H_2SO_4	220	440	28	85	5	6	¼	¼	11	20 at 3 or 10 at 10	8½	12½	12	14	115	1·9	3·8	85 Current efficiency. 93 to 95	Kennedy, Crompton, engineer, of Kensington and Knightsbridge Company.
	17		340	680	42	135	8	9	¼	¼	17		13½	12½	12	14	182	1·9	3·8		
	21		420	840	52	170	10	11	¼	¼	21		16½	12½	12	14	220	1·9	3·8		
	31		620	1,200	78	250	15	16	¼	¼	31		29	12½	12	14	460	1·4	2·8		
	61		1200	2,400	152	500	30	31	¼	¼	61		54½	12½	12	14	880	1·4	2·8		
Atlas....	No. 1	Block composed of plates made of oxides and salts of lead. H_2SO_4	150	$\left(\frac{2+1\cdot8}{2}\right)150$ 285	8	16 normal 10	10	10	0·4	0·4	—	—	7	6·29	12.57	13.75	Plates, 17·63 Acid, 6·6 Vessel, 2·2 to 8·8	9·6 per lb. of plates. 5·4 to 7 per lb. of total weight.	16·1 per lb. of plates. 8·6 to 10·9 per lb. of total weight.	—	—
Roberts...	M'dif'd Faure twin plate.	Lead alloy, H_2SO_4 combined with an alkaline solution.	75	162	15	Practically unlimited.	2	3	9-32	9-32	18 9-12	4	7½	2½	10	12	20	3·75	8·01	87 to 93, according to rate of discharge.	G. M. S. Wilson, sec. Acc. Co., Toronto. Wm Roberts, Elec. Acc. Co., Toronto.
			150	325	25		4	5	9-32	9-32	33 9-12	4	7½	5	10	12	38	3·95	8·55		
			250	545	35		4	5	9-32	9-32	63 9-12	4	9½	5	12	13½	70	3·55	7·71		
			450	990	50		8	9	9-32	9-32	108 9-12	4 (about)	9½	10	12	13½	110	4·09	9·00		
Legay.....	—	Plates made of lead wire rope formed by Planté's process.	191	364	20 amperes	200 amperes	4	5	⅜	⅜	75	—	9	9	9	11½	65 Plates, 44·1	3·07	5·6	—	Laboratory of Société Internationale des Electriciens.
Tudor.....	VII.—A	Lead.	240	456	18	24	—	—	1·3	1·3	—	—	—	—	—	—	112·2	2·1	—	—	—
	D	Lead peroxide in dilute sulphuric acid.	168	321	48	60	—	—	1·3	1·3	—	—	—	—	—	—	112·2	1·5	—	—	—

[For more extended descriptions of storage batteries and the principles involved in their construction and method of operation, the reader is referred to the following works: *The Chemistry of the Secondary Batteries of Planté and Faure,* by Gladstone and Tribe; *The Storage of Electrical Energy,* by G. Planté; *The Electric Accumulator,* by E. Reynier; *Complete Handbook on the Management of Accumulators,* by Sir D. Salomons; *Accumulateurs Electriques,* by René Tamine; *Les Voltamètres-Régulateurs,* by E. Reynier; *Die Accumulatoren fuer Elektricitaet,* by E. Hoppe; *Storage Battery,* by J. T. Niblett. Also the exhaustive researches of Ayrton (*Proc. London Inst. Elec. Eng.*, 1890); Richardson (*Journ. Soc. Arts,* London, December 4, 1891). Consult also the electrical journals.]

Stoves, Air Heating: see Air Compressors.

STOVES, HOT-BLAST. During the past ten years a marked improvement has been made in blast-furnace practice in the universal introduction in large furnaces of fire-brick stoves instead of the iron-pipe stoves formerly used. The improvements have consisted in making them much taller, and in providing better facilities for cleaning them and better

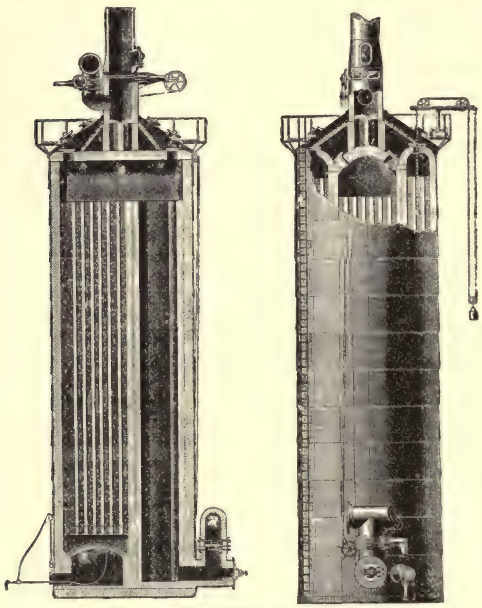


FIG. 1. Fire-brick stoves. FIG. 2.

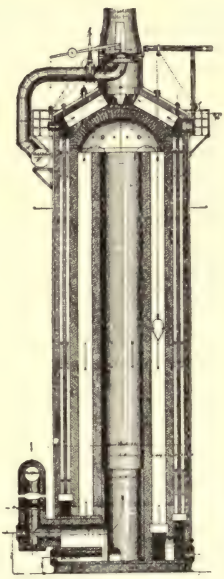


FIG. 3.—Hot-blast stove.

valves for distributing the gas and air. It is now generally customary to provide a short chimney on top of each stove, instead of one tall chimney for a series of stoves, connected to them by underground flues.

The Gordon-Whitwell-Cowper Fire-brick Stove, built by the Philadelphia Engineering Works, is shown in Figs. 1 and 2.

The arch spanning the combustion chamber and covering the first down pass has a span of just half the diameter of the stove, under which there is ample play for the gases, giving every opportunity for a utilization of all the checker-work of the down pass. On top of this short-span arch are built the flues to convey the gases from the top of the chimney pass to the chimney and the bottom brickwork of the chimney proper. To reach the chimney the gases pass down to the bottom and up the chimney pass. The gases from the combustion chamber enter the down pass, and having passed through it, enter through large arches into the chamber beneath the two symmetrical passes, forming a chimney pass, and rising through them, give off their remaining heat to the checker work, and are received on top into chambers above the checker-work. From each of these segmental passes there are two flues or passages, making four in all, leading to the base of the chimney. The checker-work in all cases has $4\frac{1}{2}$-in. walls and 9-in. openings, which are either square or circular.

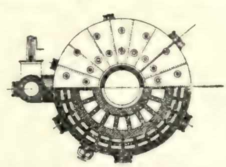


FIG. 4.—Hot-blast stove.

Massick & Crooke's Hot-blast Stove is shown in Figs. 3 and 4. This is an English form of stove recently introduced in the United States by McClure & Amsler, of Pittsburgh. The shell is the ordinary wrought-iron cylinder, with a conical-shaped top. Each stove has its own draft stack. In the center is a large combustion chamber, into which the gases are admitted at the bottom, thence passing upward and down through a series of large segmental-shaped flues, and upward through smaller flues to the escape at the top. The mushroom chimney valve, down when the gases are burning, and up when the blast is on,

works automatically: the pressure of the blast when on closes it, and when the pressure is relieved it opens, being counterbalanced as shown. From the lever a wire is attached, which reaches to the ground, so that the valve can be held closed to retain the heat during any temporary stoppage of the furnace. A door is provided in the stack, so that ready access can be had to this valve, either for cleaning or replacement, if this should become necessary. When the valve is closed by the incoming blast, the volume of air impinges upon the under side, breaking its force before reaching the brickwork, thus preventing the cutting of the brick, as takes place in some stoves of other types. Both this and the cold-blast valve are readily regulated from the ground. One advantage in this stove, especially in localities where there is a scant supply of water, is that it has but one water valve—the hot-blast valve. This valve is of solid cast-iron. Water is only used in the stem and seat ring. The valve and stem being two separate pieces connected together by a pin or bolt fitting loosely in the holes, finds its bearing on the seat, should the seat in any way be out of level. On the stove, on the outside of these flues, there is an ingenious arrangement of flyback relief doors, which, suddenly opened, when the blast is on, causes a rapid movement of the air in the direction of the opening. For cleaning, caps are taken off from the 2½-in. pipes on top, through which pipes a chain is dropped, connecting at the bottom with an open steel scraper fitting the opening. This is drawn to the top by the portable crane shown, and back again, freeing the walls of all adhering dust. The strong points in these stoves are moderate first cost; minimum of water valves, always a source of trouble and cost; thickness of walls, storing up the heat; the proper burning of the gases throughout the stove; ease in making repairs to brickwork. The first stoves built in this country were put up for Messrs. Shoenberger, Speer & Co., Pittsburgh, Pa. They were three in number, 16 ft. 6 in. in diameter and 57 ft. high to the eaves; the furnace was 14 ft. bosh and 62 ft. high, at that time making 450 to 500 tons per week with pipe stoves. The difference found on blowing-in the improved plant was at once apparent; the output rose to 800 tons per week, and the fuel consumption diminished to 1,900 and 2,000 lbs. per ton of iron, instead of from 2,700 to 3,000 lbs. See FURNACES, BLAST.

Straightening Machine: see Rolls, Bending.

STUMP PULLERS. Machines for clearing lands of stumps without the use of methods involving explosives.

The Chamberlin Stump Puller has three legs from 12 to 18 ft. high, according to size of machine. The legs are bolted at the tops to a round iron cap with a concave depression in

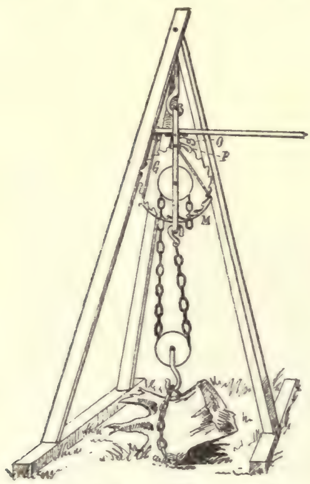


FIG. 1.—The Bennett stump puller.

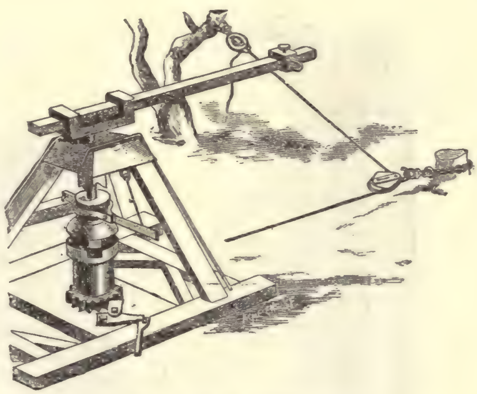


FIG. 2.—Harvey's stump puller.

its upper surface, into which fits a convex washer, on which rides a large internally threaded nut. The lifting screw of the machine passes downward through the nut. The cap and washer constitute a ball-joint, and allow the lifting screw to work at any accidental angle and still maintain a safe bearing on the tripod. The screw has a double thread, beveled. A drooping sweep, attached above to the nut and operated at the lower end with a horse, rotates the nut and lifts the enclosed screw. The latter is to be attached by means of a chain and hook to one of the side roots of the stump to be removed. Two of the legs are fitted at the foot with wheels, and the third with a shoe and draw-hook, to which horses are attached to move the machine from stump to stump, though for long distances a wagon is needed. It is possible for only one man, with a team, to operate the apparatus, but one horse will easily lift the stump as fast as three or four men can clean it of earth. From four to six circuits of the horse, according to the size of the machine, raise the stump one foot, and it should be cleaned as it is being pulled, leaving the dirt in the hole instead of at one side.

The Bennett Stump Puller, shown in Fig. 1, requires no horse. It hangs from a tripod, the feet of which are carried on runners for convenient locomotion. The whole operating parts depend from a swivel supported by a clevis. They consist of a large ratchet wheel having a small sheave fastened at one side, upon which is to be wound the lifting chain by the consecutive upward and downward movement of the hand lever, which rotates the ratchet wheel by means of a dog, while another dog prevents the ratchet wheel from reverting. The lever can be shifted on a notched fulcrum so as to change the leverage for greater or less strains ; thus the ratchet wheel may be moved through an arc covered by several of its teeth, when the work is light, for each vibration of the hand lever, greatly expediting the work. A lower pulley is used in very heavy work, doubling the power at the sacrifice of speed. The lifted stump is lowered to the ground steadily by the use of the brake, *M*. The hook, *O*, is hooked over the end of the short pawl, *P*. The link, *G*, is hooked over the end of the brake, *M*. The hand lever is then depressed, permitting the pawl, *H*, to disengage by the action of the spring in the hook, *O*. The weight of the stump then causes it to run down according as the hand lever is eased up. A spring, *T*, serves to restrain the link, *G*, from flying away from the large ratchet wheel while the operator is plying the hand lever.

Harvey's Stump Puller, shown in Fig. 2, pulls trees as well as stumps, as it may be placed at a distance from the work, and the stump or tree pulled in any direction by introducing an intermediary block. In the drawing, one of the corner posts is omitted, to expose the construction. It consists of an upright loose drum and ratchet, through which passes a shaft, round within the drum, and square at the upper portion, to carry with it a clutch with teeth for engaging and rotating the drum. The shaft has top and bottom bearings, and projects at top through an iron cap, which surmounts the timber framework of the machine, and is there fitted with a sweep seat for the sweep lever, to which one horse is attached to do the work. In practice, the machine is set in the ground firmly, and used without change of position to clear stumps from the surrounding land to the extent of as much as two acres of area without removal. Should any stump stand where the cable used in connection with the winding drum interferes with either corner post of the machine, the horse is made to travel the other way, winding the cable onto the opposite side of the drum, thus allowing the cable to swing clear. The safety pawl is held to the check ratchet by a spring, and is so made that it holds in either direction in which it may be set. The power of this machine can be indefinitely increased by the use of block and tackle attached to a second stump as a purchase, and it is therefore specially useful in regions of heavy timber, where the stumps are large. It is known as the "California" stump puller.

Sugar Machinery : see Evaporators.

SUPERHEATER, STEAM. *The Bulkley Steam Superheater* is shown in Figs. 1 and 2. It consists of a group of cast-iron pipes filled with iron wire coils closely packed, the surfaces

FIG. 1.—The Bulkley superheater.

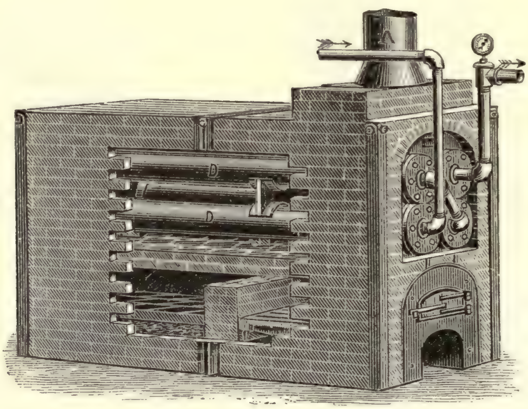


FIG. 2. –The Bulkley superheater.

of which act as additional heating surface to that of the cast-iron pipe to transmit heat to the steam which is passed through the pipes. The group of pipes may be set either in the rear of the steam boiler furnace, or in a special furnace, as shown in Fig. 2. The latter plan is preferable where a high degree of heat is desired. The steam may be superheated in this apparatus to 1,000° F. Steam of from 500° to 700° temperature is frequently used in chemical, oil, gas works, etc. The temperature is ascertained by a pyrometer set in the outlet steam pipe, as shown in the cut.

SWAGING MACHINES. Figs. 1, 2, and 3 represent the Dayton swaging machine, as used by the Excelsior Needle Co., at Torrington, Conn., for the swaging of needle blanks. It contains a revolving shaft having across its end a mortise or groove, and a

pair of sliding dies. Around this is arranged a cylindrical shell, and there are rollers between the dies and the shell, having their axes in ring bearings, so as to roll around within the shell by the action upon them of the dies. The ends of the dies come into contact with the rollers successively, and these being at opposite sides within the shell, act as rolling-toggles to press the dies together. In this manner there are as many closures of the dies at each revolution of the shaft as there are rollers in the circular range, and the parts are constantly in motion, so that there is an extended wearing surface on the interior of the shell and the exterior of the rollers. Hence the apparatus is very durable, and there is but little friction of the parts. The partial sections represent enlarged views of the dies and of the grooved shaft. The dies fitted in the groove are double—that is to say, there is a die face at each end of the blocks, *C C*, and there are followers, *C′ C′*, against the rounded ends of which the rollers, *R*, act in the swaging operation. When the die faces in the center are worn they are resurfaced and rebored, and it becomes necessary to use filling pieces to compensate for the metal removed. These filling pieces or shims, which may be of any convenient thickness or number, are placed between the blocks, *C* and *C′*. The die blocks having faces at both ends allow of their being turned end for end and used for a longer period without requiring to be resurfaced and bored. The dies and rollers do not slide on one another, but the contact is a rolling movement. Hence, there is but little friction, and the power is expended to the best advantage in compressing the article that is placed between the dies, thereby cold swaging the same, so as to reduce a wire to a needle blank, or to straighten or point wires or rods, or to straighten and render rods or shafts uniform in size. The main casting, *B*, is fittted with a steel ring, *H*, against which the rollers, *R*, bear. These rollers are mounted and turn on spindles, the ends of which are cut down so as to fit in narrow slots cut in the ring bearings, *G* and *G′*. The manner in which this is accomplished is clearly shown. There are eight rollers in this case, though there may be more or less. The rollers roll upon the interior surface of the

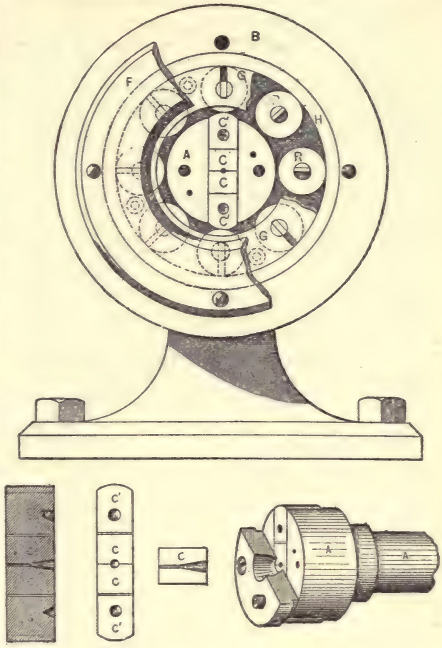


Fig. 1.—The Dayton swaging machine.

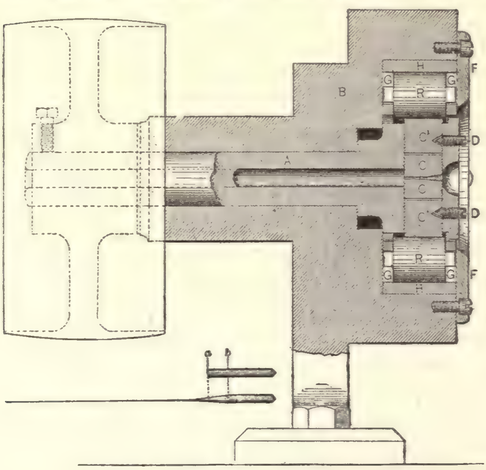


Fig. 2.—The Dayton swaging machine.

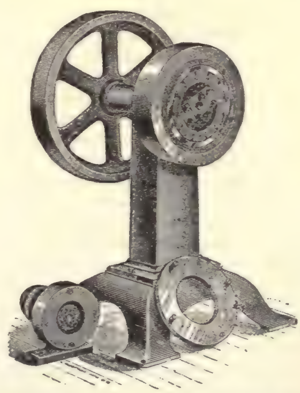


Fig. 3.—The Dayton swaging machine.

ring, *H;* and the ends of the dies, *C′ C′*, as they are revolved, come into contact with the rollers in succession, and act to turn such rollers progressively, and each roller forms a toggle between the interior surface of the shell and the end of the die. The latter is closed to the full extent when the center of the die is in a radial plane passing through the axis of the roller with which the die is in contact. The shaft, *A*, is tubular for the passage of the

wire, rod, shaft, or bar that is operated on, and its grooved portion is of enlarged diameter. If the shaft is revolved by the pulley, the article to be acted upon will only require to be fed in gradually, and be free to be revolved by the action of the dies as they move slightly while grasping the work.

In Fig. 2, *D D* are screws passing through a plate secured to the face of the shaft, *A*. The points as shown project into enlarged holes in the blocks, *C′ C′*, and limit the extent of outward motion of these. An outside ring, *F*, is screwed to the casting, *B*, making the machine ready for work. Where two dies are used there must be an even number of rollers, so that they act at opposite sides of the shell. Three-die machines built on the same principle require 6, 9, or 12 rollers, the dies being placed at angles of 120°. Near the bottom of Fig. 2 is shown a specimen of work done in the machine—a drawn-down sewing-machine needle blank. Comparison of the lower with the upper of the two engravings, which latter represents the blank originally, shows that the whole amount of metal in the elongated portion corresponds to that embraced between the lines, *a b*. The diameters of the blank originally and of the drawn-down portion are 0·081 and 0·012 in. respectively. At the works of the Excelsior Needle Co. a number of the machines are engaged exclusively in the swaging of sewing-machine needle blanks, though obviously they are applicable to a variety of other work. Machines of larger size are used for pointing rods preparatory to drawing into wire, and also for working in iron and steel in various lines of manufacture.

SWITCHES AND SIGNALS, RAILROAD. Road Signals.—The practice has become quite pronounced in favor of the use of semaphore signals for the purpose of protecting the movements of trains, as the semaphore most easily lends itself, through the simplicity of its form, to all of the many requirements of traffic. The most prominent forms of the semaphore are the home, distant, and dwarf signals, all of them modifications of the same idea.

Fig. 1.—Home signal.

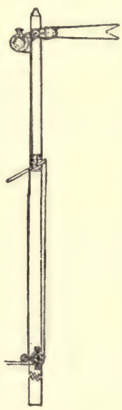


Fig. 2.—Distant signal.

Home Signal.—The home signal, Fig. 1, consists of a blade about 5 ft. long, with a square end, mounted on a post about 25 ft. above the rail level. It is usually painted red on the side toward approaching trains which it governs, and white on the other side. On double track, right-hand running, the blade points to the right; on double track, left-hand running, the blade points to the left in some cases, and in others to the right. When in a horizontal position, or showing a red light at night, it indicates danger or stop. When inclined at an angle of from 60° to 90°, or showing a white light at night, it indicates safety, or go ahead. It is only used in connection with movements in the direction of the traffic on the main track, or to control movements from the main track to facing point diverging tracks, or facing point cross-overs.

Distant Signal.—The distant signal, Fig. 2, consists of a blade about 5 ft. long, with a forked end, mounted on a post about 25 ft. above the rail level. It is usually painted green on the side toward approaching trains which it governs, and white on the other side. Its location with regard to the tracks and the direction in which it points is the same as that of the home signal. When inclined at an angle of from 60° to 90°, or showing a white light at night, it indicates that the home signal in connection with which it works is in the safety position, and that trains may proceed with speed. When in a horizontal position, or showing a green light at night, it indicates that the home signal is probably at danger, and that trains must proceed with sufficient caution to enable them to stop before reaching the home signal, if necessary. It is used always in connection with a home signal, and serves only to show the position of the home signal, which controls movements over the fastest and most important route.

Dwarf Signal.—The dwarf signal, Fig. 3, consists of a blade about 12 in. long, with a square end, mounted on a post about 2 ft. above rail level. The painting of the blade, its relative positions of danger and safety, and the position with regard to the tracks are the same as described in the case of the home signal. It is, in fact, a diminutive home signal, but is used only to control movements in a reverse direction on double track, and for movements from side track to main track, and from side track to side track.

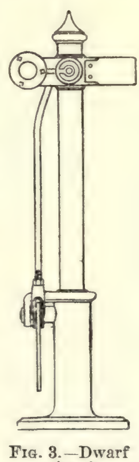


Fig. 3.—Dwarf signal.

The great advantage of the semaphore form is, that identically the same signal can be used for both block and interlocking purposes.

Block Signals.—The question of blocking a piece of track has resolved itself into the two principles of time and positive block signaling. The time signals are most prominently represented by the Fontaine signal, which consists of a track instrument controlling a dash-pot and the operation of some clock-work which may be set to run any desired number of minutes after the passage of a train. The two great objections to this method are: First, that it is not at all certain that a train has passed out of the block simply because the hand indicates that it has been gone a certain number of minutes; and, second, that the indications of the signal are visible at only a short distance.

Positive Block Systems are to be divided into two classes: First, that class which is operated by men stationed in cabins a certain distance apart, but having electrical communication with each other, and, second, by those signals which are controlled entirely by the presence of a train in their section, or automatic signals. The most successful of the first of these two methods is the Sykes system. The Sykes system is the application to an ordinary block system of certain electrical and mechanical devices which insure the fact that the signal governing the entrance to a given block cannot be cleared until the last train which entered that block has passed out of it, and the operator at the end of the block has given his consent. These results are secured by the use of a Sykes lock instrument and an interlocking relay, which are illustrated in Fig. 4, and a very short insulated section of track, with proper metallic circuits connecting the same, together with a bell wire or telegraph line for communication between adjacent block stations. The Sykes lock instrument is located in the operator's office, immediately over the lever by which he controls his signal. The interlocking relay is located in any convenient place, usually in a closet. The insulated section of track is located at the entrance of the block, and is usually about 60 ft. long. The bell-wire push buttons are located near the signal lever and the Sykes instrument. The operation in practice is as follows, everything being normal; levers home, signals at danger, and tracks unoccupied. If the operator desires to allow a train to enter one of the blocks which his signals control, he notifies the operator next in advance by his bell wire or telegraph line; the advance operator, if everything is all right, responds by "plunging" on that instrument which connects with the signal lever of the man in the rear. This has the effect of releasing the signal lever at the original block station.

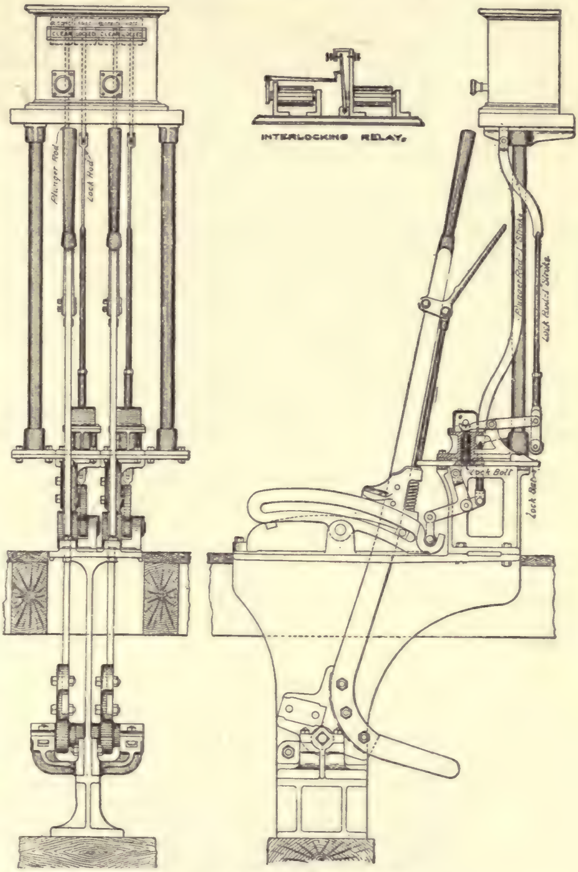


Fig. 4.—The Sykes block signal system.

The only function of the Sykes system so far alluded to is that by which one operator, on request of an adjacent operator, may "plunge" and thus release the latter's signal lever. The additional and important function of the combined apparatus is to prevent an operator from plunging a second time until the train for which the preceding operator desired to clear his signal has passed into, through, and out of the block in question. This result is secured by the combined action of the Sykes instrument, the interlocking relay, and the insulated section of track. When an adjacent operator "plunges" he passes a current through the electro-magnets of his neighbor's instrument, and in that manner releases the signal lever. When the plunger, however, is released and forced by a spring at its rear out of its original position, a rod is released, which drops down in front of the plunger and prevents it from being forced in again until the signal lever above which it is situated is reversed. The function of the insulated section of track is to automatically restore the interlocking relay to its normal position, which has been disturbed by the act of plunging. This method of block signaling has been applied to a limited extent in the United States. It is, however, extremely expensive to operate, and in its simple form is somewhat objectionable from the fact that if a train should leave the main track between any two block stations it would be necessary to send the following train past a block station with a hand signal, for the reason that the towerman in advance would be unable to release the man in the rear more than once between the passage of any two trains.

Automatic Signals.—The best known automatic signals are the Union electric signal

and the Westinghouse pneumatic signal, both owned and manufactured by the Union Switch and Signal Co , and the Hall signal, owned and manufactured by the Hall Signal Co.

The Hall Signal is described in *Appletons' Cyclopædia of Applied Mechanics*, but certain changes have been made which permit the entrance of a second train into an already occupied section, while still maintaining a danger signal in its rear. This is accomplished by the intervention of a combination of relays and track instruments, whereby the second train on passing the clearing track instrument for the section which it has just left cuts out the clearing track instrument for the section which it occupies, so that the first train cannot clear the signal for that section.

The Union Electric Signal and the *Westinghouse Pneumatic Signal* both depend funda-

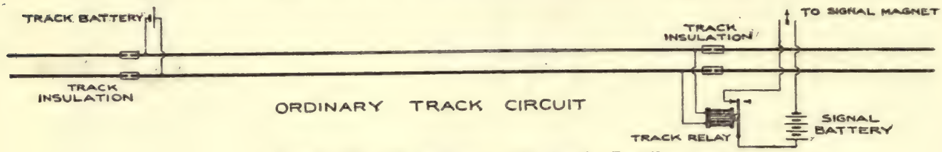


FIG. 5.—Electric and pneumatic signal. Details.

mentally on the use of the track circuit, which is illustrated in Fig. 5. The track circuit is a section of both rails of a piece of single track in which the ends of adjacent rails are connected by a piece of wire (see Fig. 6), and the ends of the rails in one section are insu-

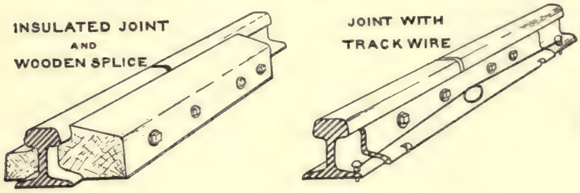


FIG. 6.—Track circuit.

lated from the ends of the rails in the section adjacent to it. In each section the ends of the two lines of rails of one end are connected together through a battery, while the two lines of rails at the other end of the section are connected by a relay which controls the signal circuit. The presence of a train on any portion of a block, or the opening of a switch, or the breaking of a rail will interrupt the track circuit, and thus set the signal to danger, which is operated by it. So far this method is common to both systems.

The Union Electric Signal consists of a combination of clock-work and electric mechanism which is directly controlled by the track relay mentioned in the description of the track circuit. The motive power consists of a heavy weight. In the past this signal has been built usually as a disk signal, with a continuous motion to the right. The demand for semaphores has, however, caused a change to be made in its form which has entailed certain alterations in the method of transmitting the motion from the operating mechanism to the vertical shaft on which the semaphores are mounted. This motion is now reciprocal instead of continuous. The present external appearance of the signal is shown in Fig. 7, the signal presenting alternately the edge and surface of its two blades to the view of an approaching train. The blades, which are of the ordinary home or distant signal form, as the case may be, are placed at right angles to each other on a revolving shaft, which moves through an arc of 90° in one operation, and returns to its original position in the next. The mechanism operating and controlling this signal is outlined in Fig. 8. The rotary movement of the shaft, *S*, obtained by the weight passing over a sprocket wheel secured to it, is transmitted to one of a higher speed in a second horizontal shaft immediately above it, to which the cross, *C*, is secured by means of a large gear wheel and a pinion. The motion of this shaft,

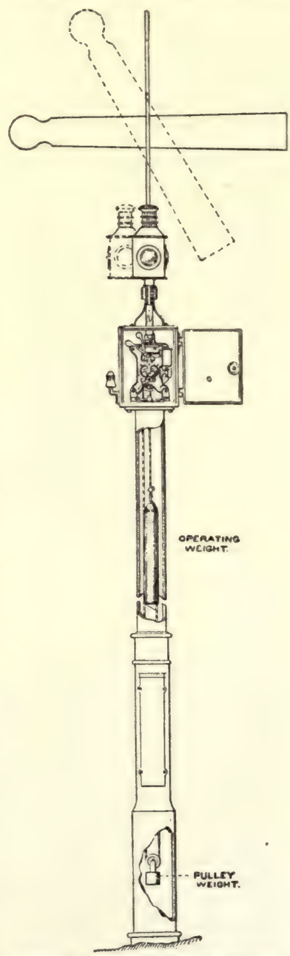


FIG. 7.—Union electric signal.

besides revolving the cross, *C*, causes a vertical shaft projecting through the top of the machine to revolve at the same rate of speed through the engagement of two beveled

gears secured to them. This vertical shaft is the one from which the signal banner is operated. The cross, *C*, on the intermediate shaft is that part of the driving mechanism by which its operation is controlled. The shaft, *S*, is the means by which the weight is wound up, and is also used to operate the device by which the danger position of the signal is insured when the weight has nearly run down. Secured to the frame of the machine is an electro-magnet, *M*, and horizontally above it is pivoted its armature bar, *A*, the outer end of which projects between two peculiarly shaped levers, *D* and *E*, known as detent toes, and engages one or the other of them when they are elevated, depending upon the condition of the electro-magnet. As shown in the cut, the magnet is demagnetized, and the detent toe, *D*, is held in the upright position by the armature, but should the magnet become charged and the outer end of its armature bar be elevated, the detent toe, *D*, would become disengaged and would drop upon the rest, *R*, raising at the same time the hook, *H*, from engagement with the pin in the back of the cross, *C*, by striking a small pin, shown in the cut, located in the outer extremity of the hook, *H*. The cross thus released turns a quarter revolution, when it is again stopped by a second pin in the opposite side of its next arm, which engages with a second hook pivoted directly back of and on the same center as the first one. The detent toes are alternately restored automatically to their elevated positions, and consequently the hooks, *H*, to their position of engagement with the pins in the cross at each quarter turn of the cross. This arrangement entirely removes the strain and jar of the operating parts from the electro-magnet, and reduces the friction in its armature bar to a very trifling amount, thus insuring great freedom in its action. On the main spindle of the machines a thread of a very fine pitch is cut where it projects through the front of the frame, and a cylindrical nut, provided with a pin of hard rubber on one side, is placed thereon and held from turning by the guide, *G*, but permitted to travel in the direction of the length

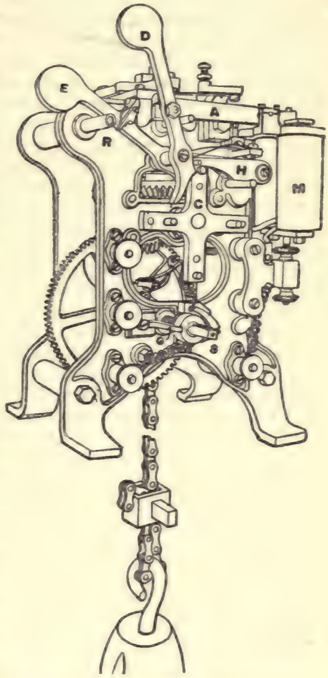


FIG. 8.—Union signal. Mechanism.

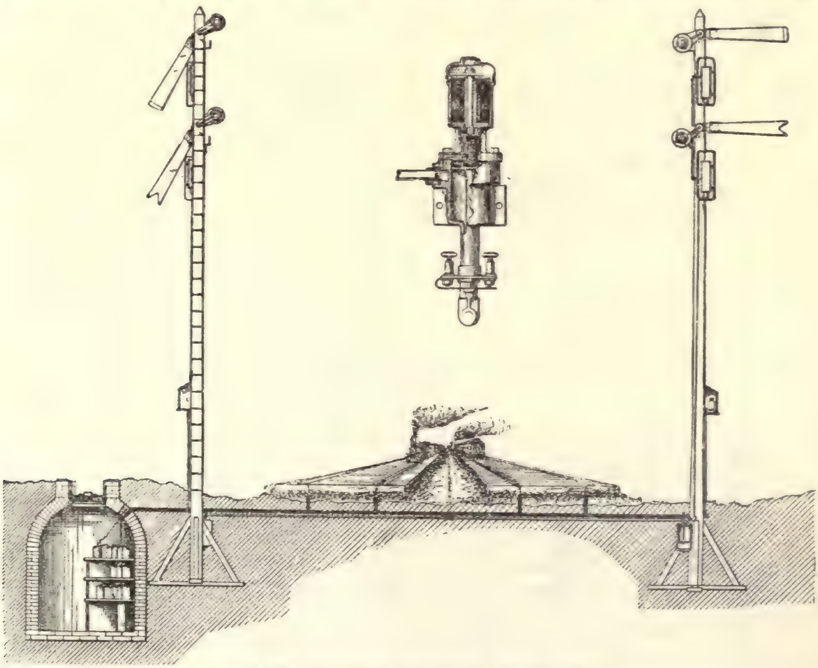


FIG. 9.—Westinghouse pneumatic signal system.

of the shaft as it turns. As the machine runs down and this nut travels outward, the

rubber pin in the nut approaches the point of contact between two springs through which the current controlling the magnet of the signal is made to pass, and causes their separation just before the operating weight has reached the bottom of the post, thus cutting off all current from the magnet, and thereby causing it to stop in the danger position before the operating power is exhausted. A considerable momentum is gained by the revolution of the semaphore arm, which would cause heavy strains were it not taken care of. This is accomplished by separating the external shaft and semaphores entirely from the rest of the mechanism. Secured to the base of the external shaft and to the top of the internal shaft are friction clutches which correspond and fit into each other. When the shaft revolves the clutch permits a revolution a little greater than the normal one, but as the sides of the clutch are inclined the shaft immediately drops back into the proper position.

The Westinghouse Pneumatic Signal system, as before stated, is controlled by the location of the trains which are passing over the road. It is illustrated in Fig. 9, and, as its name implies, the signals are brought to the clear position by the presence of compressed air in the cylinder. The magnet which controls the admission of air into the cylinder is directly controlled by the track relay, which is located on the signal post and is mentioned in the description of the rail circuit. A clear section permits the current from the track battery (see Fig. 5) to pass through the track relay, completing the circuit through the signal battery and energizing the magnet. This unseats the valve which is connected directly with the armature of the magnet, and permits the compressed air from the main pipe line to pass into the cylinder, thus driving out the piston, and lowering the signal to which it is directly connected. In actual practice the distant signal for a succeeding block is located on the same post with the home signal for the block immediately in advance. This arrangement is for the purpose of indicating to trains a considerable distance in advance as to what condition the track is in, and permits of a much higher rate of speed than if trains received their signals only at the beginning of the block on which they wished to enter. The distant signal, however, may be located any desired distance from its home signal. In connection with the pneumatic block signaling system, a pneumatic lock is located at each switch connecting with the main track, which prevents the opening of a switch after a train has entered upon that section, and which, when the switch is once opened, sets all the signals controlling that section to danger. The compressed air which operates this system is derived from air-compressors located at any convenient point near the right of way, not to exceed 20 miles apart. As will be explained further on, this air can be and is used for operating the switches at interlocking points.

INTERLOCKING.—*Mechanical Interlocking.*—The method of interlocking known as the Saxby & Farmer, and described in the previous issue, has been abandoned, and the Stevens type has now entirely taken its place. The Stevens locking has two forms. In the original form, which is illustrated in Fig. 10, the tappet, which is directly connected with the lever, operates the locking bars, which run parallel with the greatest length of the machine, or, in other words, at right angles to the motion of the levers. This is objectionable from the fact that in large machines the locking bars become very long and heavy, and the method of driving them by the tappet creates a large amount of friction and results in considerable lost motion in time. In the latest form, see Fig. 11, the Saxby & Farmer arrangement is retained, the flop of the Saxby & Farmer machine being replaced by a simple shaft connected with the link by a universal joint. A movement of the latch handle of the lever rotates this shaft and transfers the movement to the locking bar, which slides in a direction perpendicular to the plane of the movement of the lever. By this arrangement the locking is made

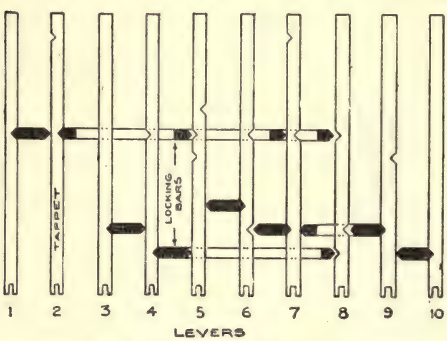


FIG. 10.—Interlocking system.

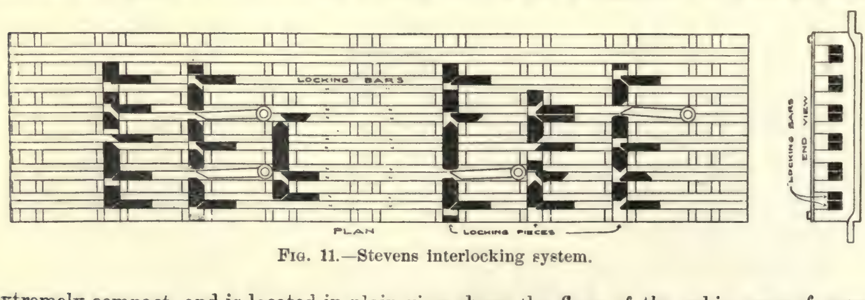


FIG. 11.—Stevens interlocking system.

extremely compact, and is located in plain view above the floor of the cabin, easy of access for cleaning and repairs.

The demands for more and cheaper interlocking have been met by the invention of several devices intended to combine the work of several levers into one. The most important of these is the selector, *S*, see Fig. 12, which is for the purpose of throwing several signals from the same lever. Theoretically, any number of signals, no two of which should be given at the same time, can be worked from the same lever, but in practice it is found best to limit this number to six or seven. The *Selector* is connected directly with the lever in the tower and also to the different switches, which, when they are in one position or the other, determine as to which signal can be thrown. The movement of a switch alternately connects or

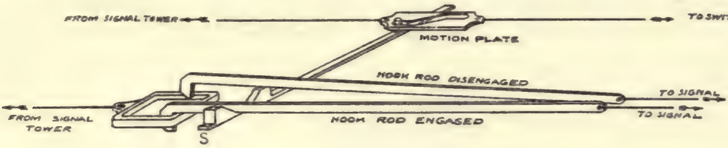


FIG. 12.—Stevens system. Plan.

disconnects each of the rods leading to the different signals with the signal lever, but never connects more than one of these rods with the signal lever at the same time.

The Switch and Lock Movement (for illustration, see Pneumatic Interlocking), which is now in general use in the United States and Canada, is a device for operating a switch, lock, and detector bar from the same lever. The original practice was to operate the switch by one lever, and the lock and detector bar from another lever, and it is still adopted in many cases. It is an expensive method, however, and is in many cases well replaced by the use of the switch and lock movement. In the operation of a switch through a switch and lock movement, the detector bar is first raised and the lock withdrawn; immediately afterwards the switch begins to move, when, upon reaching its other position, it is again locked and the detector bar lowered. This sequence of movement is necessary in order to be certain that if a train were standing over a switch, the switch shall not be moved.

The Westinghouse Pneumatic Interlocking System is the application of compressed air for the operation of signals and switches which are electrically controlled from a central point. The appearance of the machine in the tower is shown in Fig. 13. The levers, which are at

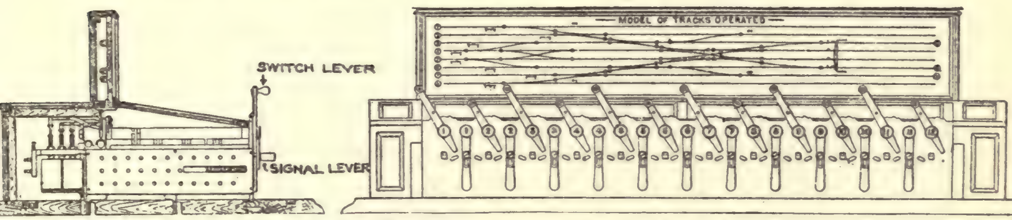


FIG. 13.—The Westinghouse pneumatic interlocking system.

the top of the machine, and which all incline to the left, are those used for operating the switches. The vertical levers, which are placed just to the right of and below the switch handles, are those which control the position of the signals.

A model of tracks is attached to the top of the machine, the switches on which receive their movement from the switch levers and which move in accordance with the position of the switch levers, showing at a glance the condition of the switches outside. Running through the machine parallel to its shortest axis are rollers formed of hard rubber, which, according to their position, make and break a contact through the different circuits. At the back of the machine are located a row of magnets connecting with each lever, called the indication magnets. In the operation of the machine, the switch lever is not moved its full throw at first, but must be held for a moment in an intermediate position. This is necessary in order that no mistake shall be made in the clearing of the signals. The first movement of the switch lever operates the valve which moves the switch. During the movement of the switch the indication circuit is temporarily closed, thereby releasing one portion of the lock on the back of the switch roller. Upon the completion of the movement of the switch the indication circuit is again broken, and permits the operator to complete the throw of the switch lever. The only communication between the tower and the different switches and signals is by insulated copper wire. In the smaller machines a gravity battery is used to furnish the current, but in the largest recent machines

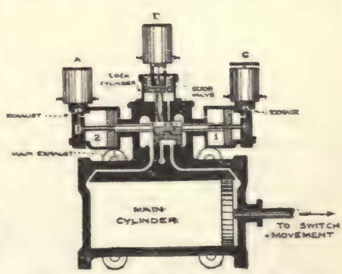


FIG. 14.—Switch valve and cylinder.

the current is taken directly from a storage battery. *The signal movements* used in the pneumatic interlocking are the same as those used in the pneumatic block signaling, which have already been described. *The Pneumatic Switch Valve and Cylinder* is illustrated in horizontal section in Fig. 14, and in external appearance, together with the switch and lock movement, in Fig. 15. The outside magnets, A and C, control alternately, depending on the position of the lever in the tower, the admission of air into the valve cylinder. The central magnet, B, controls the valve lock. By moving a switch lever in the tower, the following operation takes place: The magnet, B, is first charged (it is so shown in the drawing), which admits air into the lock cylinder and releases the slide valve, leaving it free to move as soon as the pressure shall be applied to it from cylinder *1*. Magnet C is then charged, and magnet A is discharged, permitting the entrance of air into cylinder *1* and opening the exhaust port of cylinder *2*. This forces over the slide valve to its other position, allowing the entrance of pressure to the right-hand side of the main cylinder, and connecting the left-hand side of the main cylinder with the atmosphere. The last movement of the lever in the tower cuts the current out of the magnet B, thereby locking up the slide valve in its new position.

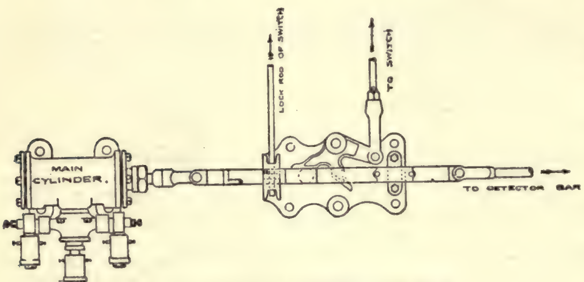


FIG. 15.—Valve and cylinder with lock.

The switch movement shown in Fig. 15 is the same as that described under the head of mechanical interlocking. A pin in the slide bar transmits the power to the wide jaw to which the switch is connected. The detector bar and lock, however, are connected directly to the slide bar, and move during its whole stroke, while the switch moves only during the middle part of the stroke.

TABULATING MACHINE. *The Hollerith Electric Tabulating System* may be considered the mechanical equivalent of the method of compiling statistics by writing on slips or cards the various items regarding the units to be compiled, one such written card repreenting a single unit, as, for example, in the case of a census, a person; and then sorting and re-sorting these written cards according to the characteristics of the individuals, and counting the number of cards finally in each group. In this mechanical equivalent the characteristics or items of the individuals are transcribed to the cards by punching holes in different positions instead of writing, and then counting and sorting these punched cards in the electrical tabulating machines. The work, therefore, naturally divides itself into—first, the transcription of the record; and, secondly, the tabulation of the data. As the system has been mostly used for the compilation of the eleventh census of the United States, the following description will be based upon such work:

In order to transcribe the particulars as to each individual from the original schedules, a keyboard punch is used about the size of a type-writer tray, having in front a perforated punch-board of celluloid. Over this keyboard swings freely an index finger, whose movement, after the manner of a pantagraph, is repeated at the rear by a punch. The movement of the punch is limited between two guides, upon which are placed thin manilla cards 6⅝ in. long by 3¼ in. high, with the lower corner slightly clipped. The keyboard has 12 rows of 20 holes, and each hole has its distinctive lettering or number that corresponds to the inquiry and answer respecting every person. Hence, when the index finger is pressed down into any one of these holes, the punch at the back stamps out a hole in the manilla card. At first glance, perhaps, the keyboard looks complicated, but it is scientifically grouped and is very readily learned. For such inquiries as are answered by one of a very few possible classes—sex, for example, which recognizes only two parties in the State—the answer is simply "male" or "female," or "M" and "F." So, too, in regard to conjugal relationships, where the answer would be either single, married, widowed, or divorced, and one punch suffices for each of these conditions.

To assist the clerks in memorizing the keyboard for punching, classification lists are used. That the work of punching became as easy as any other task requiring ordinary intelligence is shown in the fact that during the tabulating of the eleventh census, the estimated average of 500 cards per day per clerk resolved itself very soon into an actual average of 700. An expert puncher, working from 9 A. M. to 4 P. M., has done 2,521 cards, each card having on an average about 15 holes in it that relate specifically to the individual whose life history is thus condensed.

After the cards leave the punching clerks, they are kept in their Enumeration Districts, and they have now to be further punched to show the exact locality they belong to—*i.e.*, the civil division of which the enumeration district formed a part. For this purpose the space of about 1 in. across the left-hand end of the card was left blank, no portion of it being punched on the keyboard punch. This space is further divided by imaginary lines into 48 squares, in the combinations of which every enumeration district can be recorded [in the U. S. census over 40,000 such districts were thus recorded], and it is perfo-

rated by means of the "gang punch," shown in Fig. 3. The combination for any given enumeration district is arranged in this, and then all the cards of that district are passed through. From 3 to 6 cards can be punched at a time, hence the name, and pressure may be applied by either the hand or the foot. When this is done, the cards are complete.

So familiar do the clerks become with the position of the holes in these cards, they can read them off at a glance. As a means of verifying, however, a "reading board" is provided for that purpose, the same size as the card, and having also each of the 240 abbreviations in a quarter-inch space, so that when a perforated card is put on this templet the abbreviation will show wherever a hole has been punched. This templet is, practically, a reduction of the original keyboard.

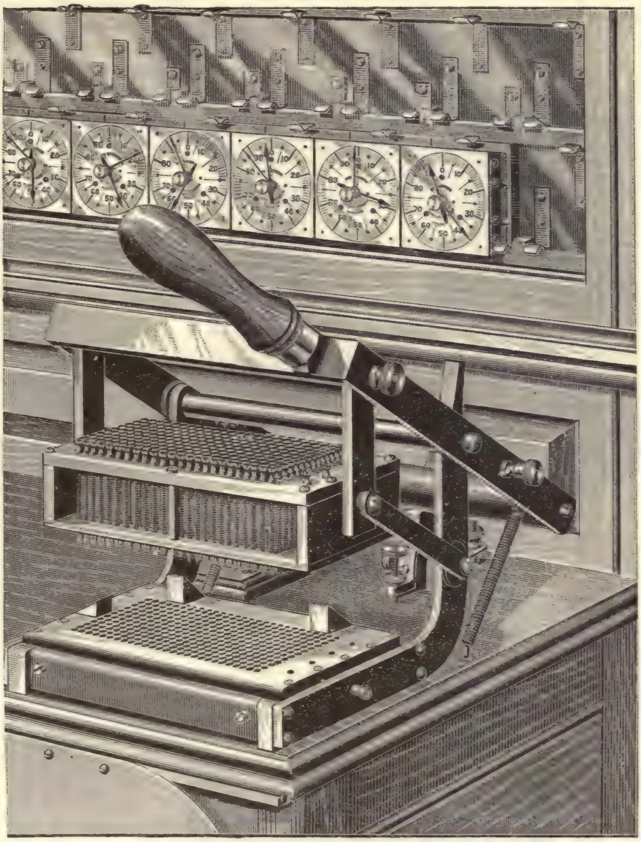


Fig. 1.—Perspective of circuit-closing press.

The punched cards are then tabulated on the machine shown in Figs. 1, 2, and 3. It consists of three main parts, namely, the press or circuit-closing device, the dials or counters, and the sorting boxes. Above a hard-rubber plate swings a reciprocating pin box, which is provided with a number of projecting spring-actuated points, so hung as to drop exactly into the center of the little mercury cups below. These pins are so connected that when a punched card is laid on the rubber plate against the guides or stops and the box is brought down, all the pins that are stopped by the unpunched surface will be pressed back, while those that correspond with punched spaces pass through, close the circuit, and count on the dials. The circuit is really closed through platinum contacts at the back of the press, not shown in the cut. In this way no difficulty is experienced from the oxidation of the mercury from the spark as would be the case without this precaution.

Fig. 2.

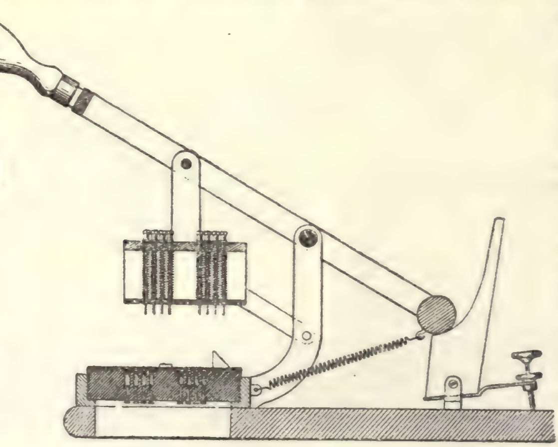


Fig. 3.—Detail of circuit-closing press.

The dials are shown in detail in Fig. 4, and may also be seen grouped in position in

Fig. 5. The front of each counter is 3 in. square, and, as now made, consists of paper ingeniously coated with celluloid, ensuring a smooth, bright, clean face. Each dial is divided into 100 parts, and two hands travel over the face, one counting units and the other hundreds. The train of clockwork is operated electrically by means of the electro-magnet, whose armature, as it moves each time the circuit is closed, carries the unit hand forward one division, while every complete revolution actuates a carrying device, which, in turn, causes the hundred hand to count. In this way each dial will register up to 10,000. A noteworthy feature of these ingenious little dials is that they can quickly be reset at zero, while they are also removable and interchangeable. The electrical connections are made simply by slipping them into frames and clips.

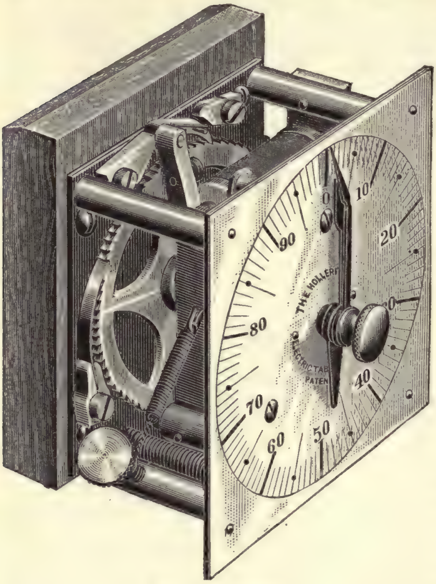


Fig. 4.—Counter.

The third element in the system is the sorting box, shown in Fig. 6 in perspective. The box is divided into numerous compartments, each of which is kept closed by a lid. The lid is held closed against the tension of a spring by a catch at the free end of the armature of a suitable magnet. If the circuit through this magnet is closed, by the press on the machine, the armature is pulled down, releasing the trigger of the lid, which is at once thrown up by the spring, and remains open until flipped back by a slight touch of the operator's hand. The connections with the machine are made by means of the short table seen at the left of the sorting box. In the cut the wires are shown attached to binding posts on a small board, but a minor change has been made by which the board is pushed in between contact clips in the machine, thus saving valuable time by obviating the necessity of screwing and unscrewing so many binding posts whenever it is desired to remove the box for any reason.

If, now, it is desired to know in a given enumeration district, or all of them, the number

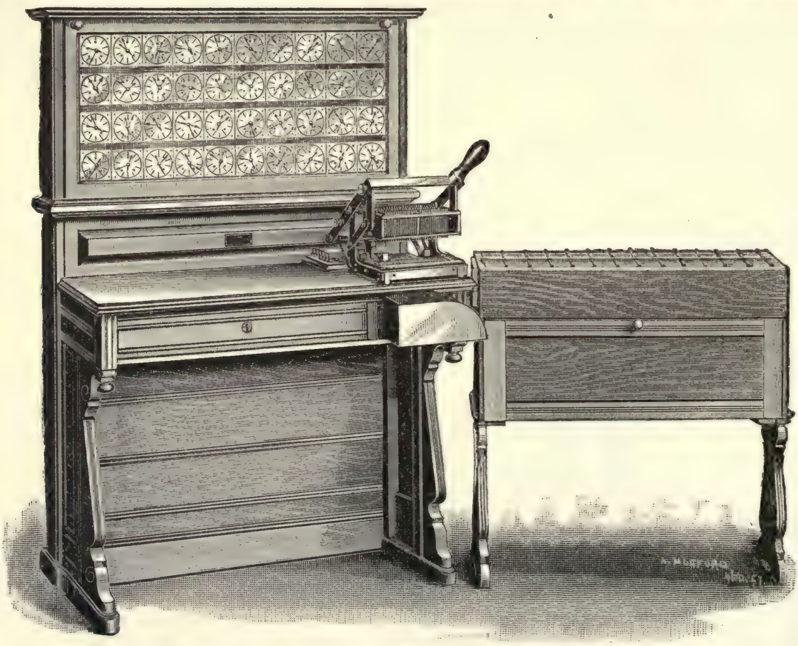


Fig. 5.—The Hollerith electric tabulating machine.

of males and females, white and colored, single, married, widowed, etc., the binding posts of the switchboard corresponding with this data are connected with the binding posts of the

dials on which these items are to be counted. If it is also desired to assort the cards according to age groups, for example, the binding posts of the switchboard representing such groups are connected with the clips into which the sorting box plug fits. The circuits being thus prepared, when a card is placed in position in the press, and the handle of the pin box is depressed by the operator so that the circuit is closed through each hole in the card, not only will the registration be effected on the counting dials, but the sorting box that has been selected for a given age group is opened. The operator releases the handle, removes the card deftly from the press, deposits it in the open sorting compartment with her right hand and pats the lid down again, at the same time bringing another card into position under the press with her left hand. It is done much more quickly than it is described. When all the cards in the tin case of any district have thus gone through the press, the record taken from the dials will show the number of males, females, white, colored, etc., while the cards will have been assorted into age groups.

The machine, however, is capable of more than this. In statistical work it is found that the most valuable information does not consist in these elementary items, but in facts that are more difficult to obtain, namely, combinations of these items. Thus, it is interesting to

Fig. 6.– Hollerith sorting box.

know how many dwellers in this country are males and how many are females; also how many are white, and how many are colored. But it is at least as essential to know how many of the white males are native born or foreign born, and how many are the children of native born or foreign parents. Hence it is desirable to provide means for counting not simply the number of white males, but the number of white males, native born, of native parents. The machines do this as easily as they do the lighter work. The principle of the relay is brought into play by means of instruments which are mounted together in the racks at the bottom of the machine. In the case just suggested the wire is brought from the binding post of the switch-board corresponding to male to one contact of the relay operated from the binding post corresponding to white. From this relay the circuit runs to another relay operated from the binding posts that correspond to native birth-places. Thence again the circuit goes to the relay operated by the binding post that corresponds to native born father, thence again to the relay operated by the binding post corresponding to native mother; and finally to a counter. It will be seen, therefore, that the counter will only be operated when a card which has been punched for "native," "white," "male," "native born father," "native born mother," and of the given age, is put under the press. If the card is not so punched the circuit remains open at one or more points, and no counting is effected. Evidently the most complex com-

bination can be effected in this manner. An elementary manner of building up the combination is shown in diagram in Fig. 7. It is simply a question of arranging the counting dials and the relays, or, if desired, the sorting boxes can be treated in the same way. When the machine is once connected up, the combination sought yields its results just as readily as though it were a single item.

There is another side of this method. We have just indicated refinement in detail of one kind, but the machine lends itself to analytical work not less than synthetical. In statistical investigation the analysis naturally becomes finer as the area enlarges, and here the sorting box is of great service. As has already been stated the cards are primarily massed in enumeration districts For such small areas, the information required groups the population under comparatively few heads. In practice it is found that such classification can generally be counted on the 40 dials that the machine embraces normally as a full equipment ; and the arrangement is made accordingly. But while counting this classification, the cards can also be assorted into groups that will form the basis of the analysis for the next larger group of territorial areas ; so that if the cards are divided into twenty groups, we shall have at the next handling of the cards, a classification of 20 x 40, or 800 heads. If, at the next step, we subdivide each one of these twenty groups into twenty more, the third handling of the cards will give us 20 x 20 x 40, or no fewer than 16,000 heads. Thus a very few manipulations will give an extraordinarily fine degree of analysis, and the compilation will have a value from its minuteness that could be reached in no other way.

Added to the ability to secure special details, finer analysis, and the economy in time and labor, we have the greater accuracy. The machine automatically throws out any card that is wrong. Suppose, for instance, that age or sex has not been punched. Where there should be a hole for the plunger-pin to go through, closing the circuit, the card is intact. The circuit is open, and the monitor bell just to the left of the press, refuses to give its cheery signal of correctness. It is then a very easy matter to refer back to the schedule stowed away in the old church across the street, and fill up the deficiency by the paradoxical process of making a hole. Suppose it was desired to connect up the machine so that only cards for New York should be counted. A missorted card belonging to Chicago would at once be rejected. The gang punches of the two cities not agreeing, the wrong cards would leave the circuit open.

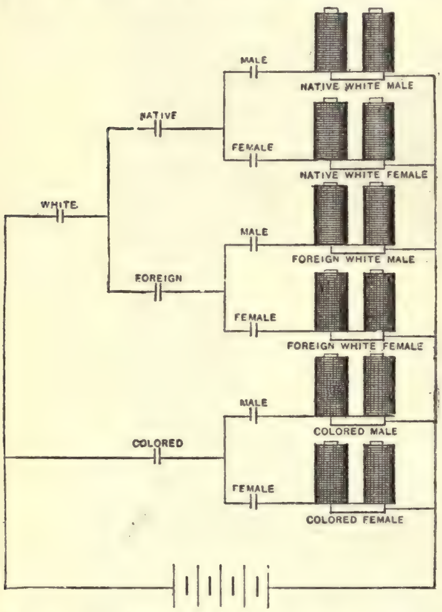


FIG. 7.—Method of arrangement for combination counting.

That all of a batch of cards purporting to represent some one class are properly assorted, is simply ascertainable by passing a wire or needle through the holes representing the given class. This could evidently not be done with written cards, and locating a misplaced written card among a million other cards is practically impossible. The probabilities of error in reality narrow themselves down to the punching, and even then the only errors that escape detection are those in which the information given, while it may not furnish the exact fact, is still consistent with the other facts punched. Even these could be eliminated by comparison or check of every card. It is to be borne in mind, too, that a card wrongly punched involves only the possible miscounting of a single unit, whereas in all previous methods the counting up on sheets has involved possible miscount at each footing up of a column.

In the compilation of census statistics, such as those of population, mortality, etc., or the bulk of the work to which this apparatus has heretofore been applied, the person forms that unit, so that each card represents simply that unit. But the census includes agricultural, manufacturing and similar statistics, and it is evident that in the figures of agriculture or manufacture, while a card might represent a farm or a factory unit, the *value* of that unit might vary greatly. Thus it might be a farm of 100 acres or of 500, and we would thus have to record *amounts*. This is done by a specially constructed machine containing a cylinder around whose circumference studs are set ; spring contact points connected to the mercury cups of the press ; a motor for revolving the cylinder, and a device for starting and stopping the motor so that the cylinder will make one revolution for each card. The operation can be readily understood. A card being put in the press, the circuit is closed through a given counter to the battery, to the cylinder of the integrating device, from one of the nine contact strips of the integrator through the corresponding mercury cup uncovered by the punched hole of the card through the plunger of the pin box corresponding to that hole, and back to the counter. At the same time, when the handle is brought down, another circuit is closed

through the magnet, which allows the train to revolve the cylinder of the integrating device one revolution. During that revolution the circuit through the dial counter will be made and broken from one to nine times, according to the contact strip which is brought into operation. Any number of counters can thus be operated at the same time, they being connected in multiple arc. The registration thus secured gives totals from any number of different sizes or amounts, and the device, therefore, answers a most useful purpose.

Tank, Glass : see Glass-making.

Tapering Machine : see Molding Machines, Wood.

Tapping Machine : see Pipe-cutting and Nut-tapping Machines.

TELEGRAPH. I. Ocean Telegraphy.—During the last few years few radical innovations in ocean telegraphy have been suggested, while practically none of fundamental importance have been introduced. There has, however, been marked improvement in details, and many valuable refinements have added to the speed and accuracy of working.

A Selenium Cable Recorder.—The currents employed in submarine telegraphy are so minute that the method first employed in receiving messages was that of the deflections of a very delicate mirror galvanometer. Later, Sir William Thomson introduced his siphon recorder, which leaves a permanent record, consisting of a continuous curve of varying amplitude, the reading of which, however, requires considerable practice. With the idea of obviating this difficulty, Eugene Baron, of Taund-Szyll, Germany, has recently devised a form of recorder in which the record is considerably simplified, and approaches more nearly to the Morse characters. Broadly stated, the deflecting coil of the ordinary siphon recorder is made to change the position of a light screen, which, moving before two small slits, admits light to and shuts it off from two selenium cells, which then act in the manner described below.

The accompanying illustrations show the details of the apparatus. The box, *K*, Figs. 1 and 2, is divided into two compartments, the first of which contains the electro-magnetic part of the relay and the selenium cells. This disposition is not essential, however, as they

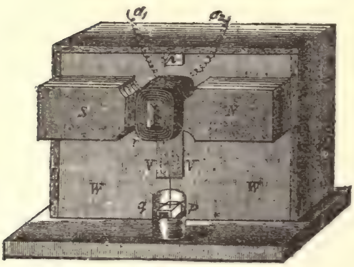


Fig. 1.

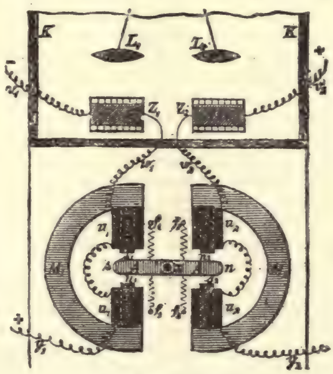


Fig. 2.

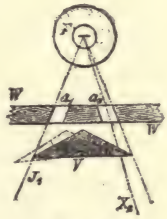


Fig. 3.

Selenium cable recorder.

can be removed to any desirable place, and the recording apparatus proper need only be in the operating room. The second compartment contains a bright source of light, such as an incandescent lamp, *F*, Fig. 3. The dividing wall between the two, *W*, has two slits, through which the light enters when permitted to by the screen, *V*. The relay consists, as stated above, of the siphon recorder coil, *r*, placed in the magnetic field of the magnets, *N S*, and deflected in either direction, according to the direction of the currents in the cable. The coil carries a downward projection in the shape of a triangular prism, *V*, Figs. 1 and 3. When the latter is in its central position it covers both slits, a_1 and a_2, and prevents the light from passing either one. A current passing through the coil deflects the latter correspondingly, and with it the triangular screen, which then permits the light to pass in the same side, as shown, in the direction, *F J*, Fig. 3. After passing the slits, the light is concentrated on the selenium cells, Z_1 Z_2, by the lenses, L_1 L_2, Fig. 2.

Light falling on the cells reduces their resistance, as is well known, and the two local batteries being in circuit with the cells, Z_1 Z_2, the current is varied accordingly. The arrangement of the recording apparatus is shown diagrammatically in Fig. 2. M_1 and M_2 are two powerful horseshoe magnets, the poles of like name being diagonally opposite each other. Between the poles of these magnets there is pivoted a bar magnet, *A*, supported by the spindle, *X*. This polarized armature can be regulated to a central position by the springs, f_1 f_2, and the coils, u_1 u_2, of very fine wire, are included in the local circuits. The poles, n_1 s_1, act, the one attractively, the other repulsively, upon the armature ; s_2 n_2 act similarly. A small difference in the strength of these four poles causes a deflection of the armature. It is apparent that as light is admitted to either cells, the armature will be deflected in one direction or the other, and the armature can be made to record these movements, either directly or through the medium of another recording apparatus, by the closing of an auxiliary local circuit.

The Cuttriss Siphon Vibrator for Ocean Cables.—The use of static electricity to

vibrate the siphon, with the object of preventing friction at the marking point of Sir William Thomson's siphon recorder, has always been the one defect in this otherwise most perfect and beautiful instrument; for, as is well-known, in damp weather, static electricity is difficult to produce and well-nigh impossible to control.

The invention of Mr. C. Cuttriss, Fig. 4, obviates all this trouble by the use of magnetism,

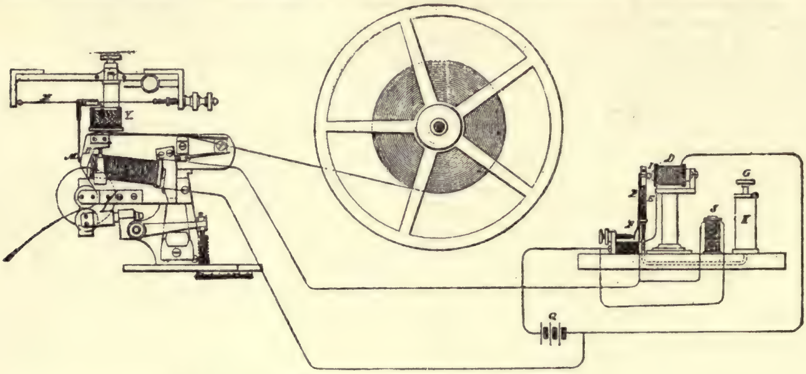


FIG. 4.—Cuttriss siphon vibrator for ocean cables.

and the instrument works just as perfectly be the weather damp or dry. The siphon, *M*, is made slightly thicker toward the point; this is caused by a small particle of iron wire, No. 30 or 32, about $\frac{1}{16}$ or $\frac{3}{32}$ of an inch in length, fastened to it by a little shellac varnish. The magnetic recording table, *B*, opposite the point of the siphon, over which the paper slip passes, is made partly of iron, and to the back of it is the electro-magnet, *C*. The principal part of the invention is the adjustable vibrator at the right of the illustration. The glass tube, *E*, and armature, *I*, which are supported by the steel rod, *P*, are vibrated by an electro-magnet, *D*. Continuous vibration is maintained by means of the battery, *Q*, and the contact points, *F*. The upright mercury reservoir, *K*, has a regulating screw, *G*, the lower end of which is made to act as a plunger; a small india-rubber tube connects the mercury reservoir with the glass tube, *E*, so that by raising or depressing the plunger the mercury can be forced and maintained at any required height in the glass tube, and by this means its rate of vibration can be changed as may be required. When a siphon is attached to the strained wire, *X*, and it has become filled with ink from the ink reservoir, *Y*, the plunger is manipulated until the siphon attains its maximum arc of vibration. A perfectly steady dotted line is then obtained, and will continue without any other regulation so long as it remains filled with ink.

Transmission of Morse Characters on Submarine Cables.—Mr. Patrick B. Delany has perfected an invention by which long cables may be operated by any Morse operator, and by which the received characters are not only greatly improved, but the rapidity with which they may be transmitted greatly increased. When the key is pressed down, a current of one polarity is sent. If it is immediately lifted up, a current of opposite polarity is sent, lasting for the short time between the downward and upward movement, forming a dot. If the key be held down, a dash is formed, not by the passage of a long impulse, but because the opposite polarity which terminates each signal is deferred until the key is lifted up. One current is the beginning of all signals, the other is the ending; the time between the beginning and the end determines whether the signal is a dot or a dash. There are no dashes sent into the line, but all currents are of equal duration and alternating in polarity.

On the 9th and 16th of September, 1888, Mr. Delany's transmitter was tried over the Anglo-American cable from Duxbury, Mass., to St. Pierre, and the results obtained more than confirmed expectations. The cable is 878 miles in length, 8,300 ohms resistance, and 256 microfarads capacity. We reproduce in Fig. 5 the record received at St. Pierre at different rates of speed, varying from 13 to 34 words per minute, with accurate timing and five letters to a word. During the same test, Mr. Delany transmitted twenty words per minute, every letter of which was received perfectly at St. Pierre, on a Morse sounder. This is by far the longest cable circuit ever worked by sound, and the speed of twenty words per minute on such a circuit is a great stride in cable telegraphy. Mr. Delany believes that he can increase the speed to thirty words per minute, and has strong hopes of working the main Atlantic cables by sound at no very distant day.

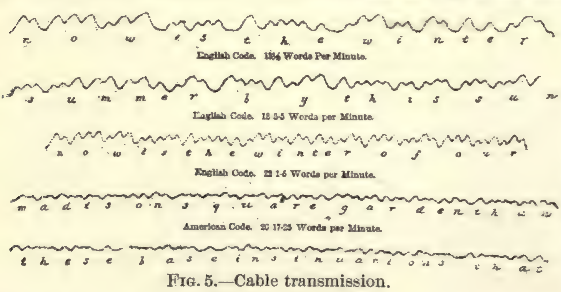


FIG. 5.—Cable transmission.

II. Multiplex Telegraphs.—*The system of Mr. Delany* is based upon two main principles: First, that of synchronism, or the simultaneous motion of similar pieces of apparatus at two different places; and, secondly, that of distributing to several telegraphists the use of a wire for very short equal periods of time, so that practically each telegraphist has the line to himself during these periods.

The combination of these principles of working by synchronism and multiplex telegraphy on the same wire was first attempted by Moses G. Farmer in 1853, using two wires, one for maintaining in synchronism the distributors which put four operating instruments in connection with the others. This was introduced by Meyer in 1878; it was improved upon by Paul la Cour in 1878, and Baudot in 1881; synchronism was perfected by Delany in 1882, and the system completed in 1884, and is now extensively used by the British Postal Telegraph department, where it has reached its highest development under direction of W. H. Preece, F.R.S., electrician-in-chief.

The instruments at each station are connected to identical "distributors," consisting of a number of segments arranged in a circle over which travels an arm. If each segment be divided into four segments, and by means of these be connected with, say, four instruments instead of with only one of them, then during one complete rotation each arm will place corresponding instruments in communication with each other four times. Or if each circle be divided into 40 segments, and each of these into four segments, then corresponding instruments will be in communication with each other forty times during each complete rotation of the arms. In the British post-office apparatus there are 168 segments, and these are grouped differently, according to the number of ways of working. Sextuplex working requires one grouping, quadruplex another, triplex another, and so on.

Two tuning forks pitched to absolutely the same note, and set in vibration by currents like an electric trembling bell, will move in synchronism, but the synchronism can not be maintained. The deposition of dirt, dust, or moisture, changes of temperature, variation of current, produce changes which affect the rate of motion. Paul la Cour, of Copenhagen, invented an ingenious way to maintain the synchronism, the principle of which has been introduced into the Delany system. A simple reed is now used as the means of keeping the distributor in synchronous motion. The electro-magnet of the reed is wound to a resistance of 30 ohms. Its local circuit includes the lever and lower contact of a relaying sounder. The correction for synchronism of the two revolving arms is effected by causing this lever to rise, thus breaking the circuit of the reed magnet when a correcting current is received.

The distributing circle is divided into 168 equal spaces, furnished with segments insulated from each other; 144 of these segments are connected to form twelve groups for telegraphing, the remaining spaces being fitted with segments for synchronizing purposes. Segments 1 and 1, 2 and 2, 3 and 3, and so on, are electrically connected together to form the groups, and each group of twelve segments thus arranged is connected to a terminal on the base of the distributor. An arm, or trailer, passes lightly over the surface and moves continuously round the circle, coming successively in contact with every segment, moving in the opposite direction to that of the hands of a watch. It is electrically connected to the line wire. In every rotation it makes 168 electrical contacts, 144 of which are for telegraphing, while the others are for maintaining synchronism.

The function of the trailer is to place the line wire successively in connection with the segments in the different groups. The currents of electricity that flow through the line wire are dependent upon the operations performed upon the telegraphic apparatus, and they are broken up into short pulsations or impulses by the momentary contact made by the trailer. The relay is of the standard form, but it is much larger; its cores are nearly 4 in. long by $\frac{3}{4}$ in. in diameter, and it is wound to a resistance of 1,200 ohms with copper wire $\frac{6}{1000}$ in. in diameter.

Working in either direction, sextuplex transmission is feasible between London and Brighton, London and Birmingham, and London and Bristol; but quadruplex is the limit to Liverpool. In one direction, however, to Manchester, even six circuits have been operated as an experiment, so that with two wires twelve circuits might possibly be worked, six in each direction.

The Patten Synchronous Multiplex Telegraph.—This system is the invention of Lieut. F. J. Patten, U. S. A., and depends for its operation upon the synchronous and uniform movement of two or more electric motors placed at distant points. It is evident that an ordinary Siemens armature in a two-pole field must reverse its current at every half revolution. If by any means two such machines be caused to reverse their armature currents simultaneously, they would necessarily move in synchronism. The system will be readily understood from the illustration, Fig. 6, which is a diagram of all the operative circuits, including two terminal stations. In the two-line system a single synchronizing line is used for controlling a movement of electric motors, and may be used to synchronize the motors for any number of lines In the single-line system the synchronizing current is used both for synchronizing and telegraphing, without either function interfering with the operation of the other. For the sake of simplicity the two-line system is selected for description.

In Fig. 6, *X* and *Y* represent two terminal stations of a telegraph line. The synchronizing line, *L L*, extends from the earth E^3 at *X* to E^4 at *Y*, reversing the polarized relays, P^1 and P^2, at these stations. At any intermediate point in the line, whether at *Y* or *X*, or midway between, is placed a revolving pole changer, the function of which is to constantly reverse a current on this line derived from the synchronizing battery, *9*. This pole changer is driven by an electric motor having independent field and armature circuits, by which

means its speed may be regulated and controlled; it is shown in the middle of the diagram. The lamps, *11*, are in the armature circuit in multiple arc, and by turning them on or off, the speed of the pole changer may be varied, the field remaining of uniform intensity excited by the battery, *10*. This pole changer sends rapidly reversed currents continuously to line, and maintains the polarized relays at X and Y in constant and rapid vibration. They necessarily beat in synchronism, and are reversed by every half revolution of the controlling motor. These alternations set the pace of as many machines as it may be desired to place in circuit. Very little current is used for this purpose, the battery line on a one hundred mile circuit having only about 30 volts potential. The current is necessarily very weak, and the vibration of the polarized relays is delicate but constant.

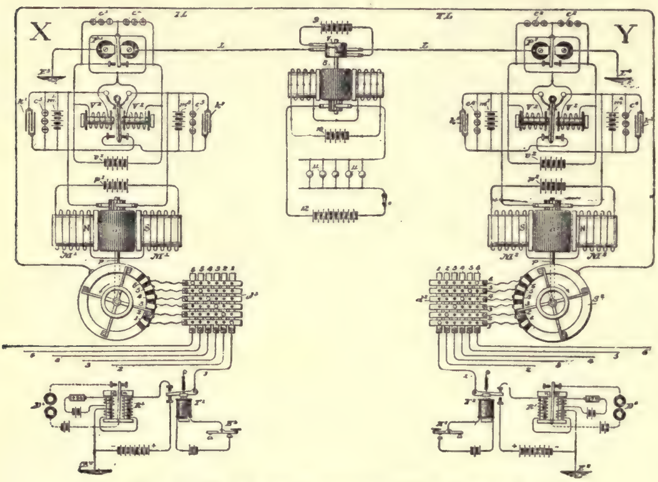


FIG. 6.—Patten synchronous multiplex telegraph.

The armatures of these polarized relays drive a powerful vibrator in the same way that a relay actuates a sounder, the vibrator being placed upon a local circuit of low tension, v^1 v^2, and this is given sufficient strength and a suitable form to both rapidly reverse and convey the heavy currents of the motor armatures. These vibrators are shown at v^2 in the diagram, which is sufficiently clear to explain their operative parts. The polarized relay, as it vibrates to and fro, places alternately one side and the other of the vibrator in circuit, and its armature is rapidly and strongly pulled first against one contact point and then the other.

It being now understood how the regulator at some intermediate station keeps the polarized relays in unison movement, and they in turn maintain the local vibrators in corresponding unison movement, it will be explained how this system of devices maintains the motors at distant stations in synchronous rotation. The motors are shown at X and Y by diagram circuits, M^1 and M^2; the fields, N S, are constantly and separately excited by the batteries, P^1 and P^2, while the armatures receive their current alternately in opposite direction from the batteries, m^1 m^3, at X, and m^2 m^4 at Y, as the vibrator armatures move to and fro.

The motor armatures are of peculiar construction, and will continue in rotation when supplied with a current of rapidly reversed direction, the connections being such that a constant polarity of the armature is maintained with reversed currents, provided the armature turns through a certain arc of the circumference at each reversal of the current. As the system is now used, they are so connected that they move one-fourth of the revolution at each reversal of current. The synchronism is thus corrected automatically four times in each revolution; it may be made eight or twelve, or more, if desired. The spindles of the armature have secured to them revolving trailer arms carrying brushes which sweep over the segmental distributors, s^1 and s^2. They are shown flat in the diagram, for clearness, but are evidently at right angles to the spindles, which in practice are vertical, as shown in Fig. 7, which represents the machine in perspective.

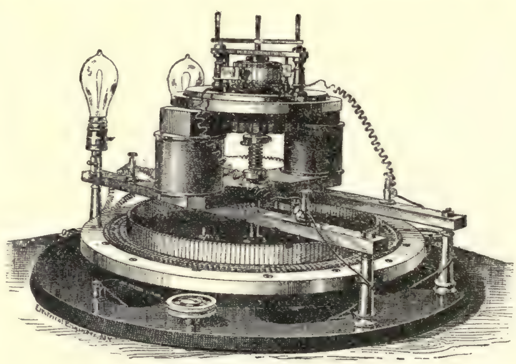


FIG. 7.—Distributor motor.

The telegraph line extends also from earth, E^1 at X, to E^2 at Y, one set of instruments being shown in detail at each end. The circuit may be traced as follows, the operator at X being supposed to be sending, and the operator at Y receiving: From earth, E^1, through the line battery positive to line, transmitter contact, t^1, switch, d^1, segment No. 1 of the distributor, and through the trailing brush to the large segment of the distributor, to which the line is connected at X;

thence over the telegraph line, $T\,L$, to the distributor parts at Y, out through the switch, d^2, transmitter back contact, receiving relay R^2, and completing the circuit at E^2.

The speed is so regulated in practice as to give each instrument, when its circuit is closed, 30 contacts with the line per second, which, admitting four contacts per revolution, would mean an average speed of 7½ revolutions per second, or 450 per minute. But as the distributor motors (Fig. 7) move at half the speed of the controlling motor in the middle of the line, this one, which carries the pole changer, is driven at about 900 revolutions per minute, producing therefore 1,800 reversals of current per minute on the synchronizing line, and a corresponding number of vibrations of the polarized relay armatures. But as four of these are required to produce a single revolution in the armatures in the distributor motors, their speed is brought to about 450, as stated.

The Field Sextuplex Telegraph.—An ingenious improvement in multiplex telegraphs is that of Mr. S. D. Field, operating as a sextuplex. Three different qualities of current are employed, viz.: a direct current of increasing and decreasing strength, operating a neutral relay ; a reverse current, operating a polarized relay ; and a rapid vibratory current, which sets a telephonic diaphragm in rapid vibration. These three currents acting upon corresponding receiving instruments, do not interfere with each other, as will be shown below ; and as each one type of working is duplexed by the well-known compensating method, the line is evidently capable of transmitting three messages in either direction, or six simultaneously.

The arrangement of circuits and apparatus by which these results are effected is shown in the accompanying diagram, Fig. 8. Both the main line and locals derive current from a dynamo. The latter is shown at F, and the armature, as will be seen, is provided with two independent sets of windings, which deliver current respectively to the commutators, E and D. The local currents are taken off the commutator, E, the circuit connecting with the three local transmitters, *1*, *2*, and *3*, which are manipulated in the ordinary way by the keys, K^1, K^2, K^3. The main current is taken from the armature from the commutator, D, this current serving to actuate the neutral and polarized relays, which are shown diagrammatically at *2'* and *1'* respectively. It will be noticed that the dynamo, F, is shunt-wound. Its armature is of 150 ohms resistance, and it has an E. M. F. of 300 volts at 500 revolutions. The shunt coil is divided so as to give a long and a short shunt at the points, G, H, depending upon whether the transmitter *2* be closed or open. The resistance of the short shunt is 540 ohms, and that of the long shunt is 6,000 ohms. Hence it follows that by pressing K^2, the armature of transmitter *2* is attracted to the front stop, and short-circuits the long shunt of the dynamo. This, of course, causes an increase of current in the short shunt, the strength of the field magnets remaining constant ; and hence there ensues a decreased effect in the line current, and it is upon this increase and decrease of the direct current that the neutral relay *2'* operates.

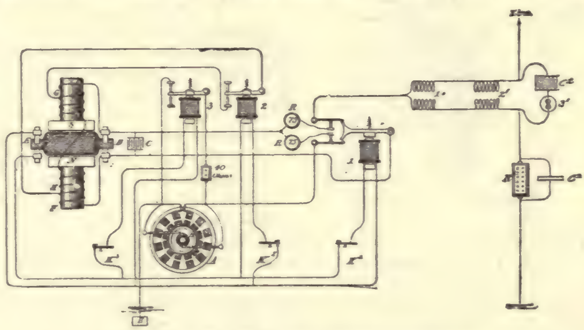


FIG. 8.—The Field sextuplex telegraph.

Transmitter *1* operates a pole changer, by which reverse or alternate currents are sent over the line, which actuate the polarized relay shown diagrammatically at *1'*. The pole changer is so adjusted as to be continuity-preserving as regards the line, but with a very slight break toward the dynamo.

It is evident that the continuous current designed to operate the neutral relay has no effect upon the polarized relay ; but the reverse currents designed for the latter would affect the neutral relay if some provision were not made to prevent this disturbance. This has been recognized by Mr. Field, and he overcomes the difficulty in a very simple manner.

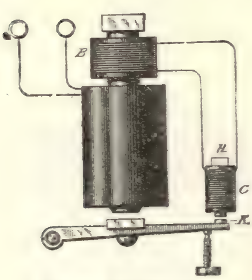


FIG. 9.—Neutral relay.

The neutral relay *2* is shown in part perspective in Fig. 9. To understand its operation, we will premise that when ordinary reverse currents are sent through a neutral relay the armature is kept in a state of vibration, breaking contact momentarily at each reversal, but being immediately re-attracted. With the arrangement of the neutral relay shown in Fig. 9, the reverse current has no effect on the armature. This result is obtained by taking advantage of the induced currents generated by the reversals. As will be seen, the core of the relay is lengthened, and has a bobbin, B, surrounding it. The latter is connected to another small bobbin, C, surrounding a core, H, which is placed opposite a small cylinder of iron, K, acting as an armature and attached to the lever of the relay. The reversal of current in the relay bobbin causes a change of polarity in the

core, and the tendency is to momentarily throw off the armature ; but at the same instant of the reversal of polarity an induced current is set up in the bobbin, *B*, which is in opposite direction to the primary, and which, in circulating through *C*, tends always to magnetize the core, *H*, oppositely to that of the main core, and hence, with a corresponding influence upon the small armature, *K*. The result of this is, evidently, that with two opposite influences acting upon the lever, it will remain stationary and insensible to the effects of the reverse currents.

We come now to the third and last method employed in transmission, which consists in sending a rapidly vibrating current over the line, which is made to set a telephonic diaphragm in vibration.

The source of the vibratory current is the small dynamo shown at *A*. From the arrangement of circuits, it will be seen that the commutator, *B*, cuts the line coils of the vibratory magneto, that is, the outer ring of magnets, out of circuit, except at the instant of passage of the poles, and thus reduces the resistance of the circuit from 160 to 5 ohms, which changes evidently occur in continuous rapid succession, sending a vibratory current over the line. These currents charge the condenser, C^2, at the distant station, which tends to increase their abruptness, and thence pass into the vibratory receiver or relay $3'$. The latter is shown in detail in Fig. 10. It consists of a horseshoe magnet, *M*, upon which are mounted the coils, *F*, through which the vibratory currents from the line are made to pass. Opposite the poles of the magnet is placed the diaphragm, *D*, which has a platinum pin, *C*, mounted on its center. Resting upon this pin is another, *B*, which is attached to the end of a lever, which, together with the diaphragm, *D*, is in circuit with a sounder, *S*. A local battery is here shown in circuit merely for the sake of clearness, the current being in reality taken from the local leads of the dynamo.

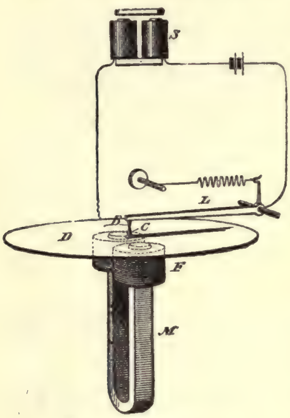


Fig. 10.—Condenser.

Now, when the key, K^3, is open, the armature of the transmitter, *3*, is on its back stop, and closes a circuit including a 40-ohm resistance, so that the current from the vibratory generator is short-circuited and does not go out over the line. When the key, K^3, is depressed, however, the armature of *3* is attracted, breaks the short circuit, and the vibratory currents then pass out to the line. Arriving at the receiver, shown at *3*, Fig. 8, they set the diaphragm, *D*, in rapid vibration, so that the pins, *B* and *C*, are given a rapid make-and-break motion ; in fact, so rapid is the motion and so short a time are the pins in contact, that the local circuit is practically open, and the sounder has not time to act, being purposely made sluggish in its movements ; the local circuit remains open, then, as long as the key, K^3, is depressed. The dots and dashes of the key are therefore received on the vibratory receiver as a series of "buzzes," which are transformed in the manner described into dots and dashes on the local sounder, *S*. Both the relays as well as the vibratory receiver are wound differentially, as in the ordinary duplex service.

The Edison Phonoplex.—The ordinary duplexing of a wire, which increases facilities between terminal points only, has been largely applied, but until Mr. Thomas A. Edison devised this new method of transmission no means were available by which the capacity of intermediate offices on a single Morse circuit could be increased. Through the use of the phonoplex system extra circuits are provided, by means of which more than double the amount of service may be derived from a single wire than is at present obtained, while its extreme simplicity of detail and adjustment places it within the easy control of ordinary operators.

The principle upon which the system is operated is induction. The instruments employed for signalling respond only to induced currents thrown upon the line by transmitting devices, which currents interfere in no way with Morse instruments in the same circuit, being made to pass around them through condensers, while Morse waves in turn have no perceptible effect upon the phonoplex apparatus ; thus, two or more independent circuits may be provided on a single wire, as will be more fully explained hereafter.

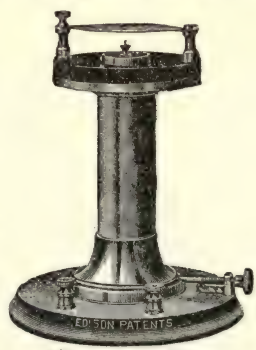


Fig. 11.—The phone.

The apparatus for the equipment of an office consists of a key, transmitter, magnetic coil, small resistance box, and the phone, which last responds to incoming signals, two condensers, battery ; and the whole is arranged to occupy no more space than ordinary Morse instruments. Fig. 11 represents the phone. A hollow column of brass resting upon a wooden base encloses the magnets. At the lower end is a rack and pinion by which these can be adjusted with reference to the diaphragm. To the center of the latter there is attached a screw-threaded pin with thumb-nut and binder at the top, and encircling the pin loosely is a split-hardened steel ring which rests upon the diaphragm. When the latter is snapped by the attraction of the momentary current in the magnet, it throws the ring violently against the stop nuts and produces a sharp, loud click,

The steel ring has a pin projecting from its side that passes between two prongs, which, while permitting free up and down motion, prevents the ring from turning and altering the sound. Over the top of the phone there is clamped a thin brass plate as a protection for the projecting screw.

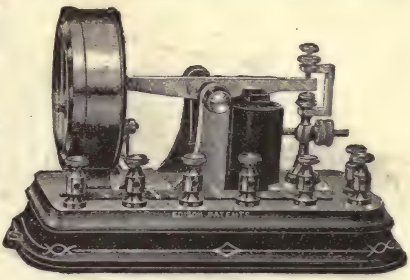


Fig. 12.—The transmitter.

The transmitter, Fig. 12, is interposed between the key and the magnetic coil. The former operates the magnet of the transmitter the object of which is to send uniform currents to the line, and also to short-circuit the phone, each time the coil battery circuit is broken, and thus obviate the annoyance which would otherwise be caused by the violent discharge close to the diaphragm.

In a small magnet, Fig. 13, is stored the energy which is exerted on the line for the purpose of operating the phones. As it is necessary to produce an instantaneous discharge, a condenser is connected around the points of the transmitter, which makes and breaks the circuit around the coil.

Fig. 13.—Magnetic coil.

The key, Fig. 14, is so constructed that when the lever is "opened," or thrown to the right, it closes the circuit around the magnetic coil through the points of the transmitter, and when "closed," or thrown to the left, it opens this battery and at the same time short-circuits the magnetic coil. The necessity for this lies in the fact that an open-circuit electropoion battery of low resistance is employed, which it is desirable to use only when occasion requires the transmission of signals, and also that the resistance of the coil has an audible effect in the phone when it remains in the line to retard incoming currents.

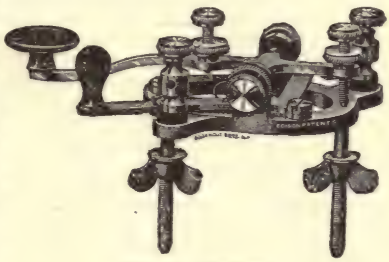


Fig. 14.—The key.

Thus, while the manipulation of the key accomplishes all the objects it is desirable to attain, it introduces no innovation, as the same movements to which operators are accustomed are maintained—"opening" for the transmission and "closing" for the reception of business.

A small resistance box, Fig. 15, is interpolated in such a way that when the current through the magnetic coil is broken on the up stroke it passes through the spools. This is to produce an audible distinction between the up and down movement as manifested in the phone, the former being lighter than the latter, so as to prevent confusion that otherwise would be occasioned by operators getting the "back-stroke."

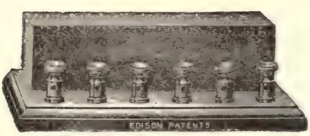


Fig. 15.—Resistance box.

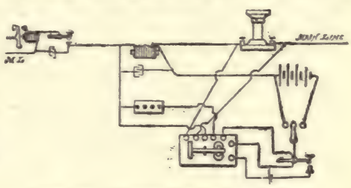


Fig. 16.—Phonoplex transmission.

The diagram, Fig. 16, shows all the instruments in place. All Morse keys and relays within the limits of a phonoplex circuit are bridged, as represented, by a condenser, through which pass the induced currents that operate the phones. It will be readily seen that the main line, which passes through the magnetic coil and through the phone, is never broken, the former being charged and discharged by means of an extra circuit around it through its key and the points of the transmitter.

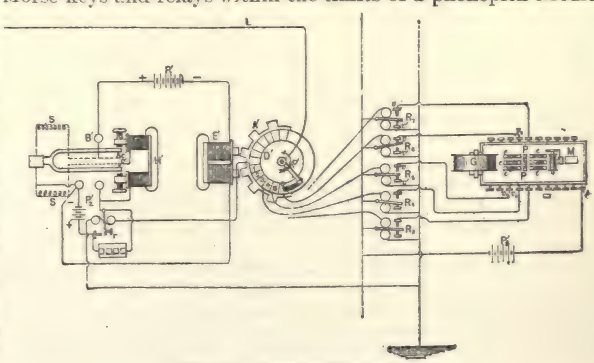


Fig. 17.—Stenographic system.

The Cassagnes-Michela Steno-Telegraph. — Among the various methods of increasing the number of words which can be transmitted over

a telegraph line, is that in which stenography is called into play, invented by Michela and perfected by Cassagnes. The stenographic system employed subdivides words into their phonetic elements, which are represented graphically by various combinations of a very small number of different signs. The apparatus consists of a key-board at one end of the line and at the other a series of type levers, upon which the various stenographic characters are carried. By pressing a key at the sending end, the corresponding lever is raised at the receiving end, and the characters are printed upon a roll of paper which advances a step after each imprint of one or more signs, according to the number of keys depressed at a time. The method employed being a phonetic one, it is applicable to any language.

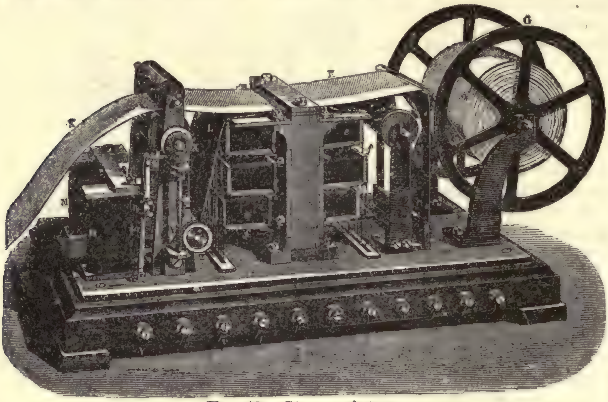


FIG. 18.—Steno printer.

The general arrangement of the receiving station is shown in Fig. 17. Each sector D' of the phonic wheel is connected with one of the polarized relays R_3, R_4, etc., which close the circuits of the electro-magnets $e\ e\ e$ through battery P_3'. The printer P in Fig. 17 is shown in perspective in Fig. 18, and consists of 20 printing levers which carry the stenographic signs. As each electro-magnet is energized it attracts its hinged armature from below and pushes up its printing lever. At the transmitting station the 20 keys on the board are connected to the sectors of the phonic wheel corresponding to those of the receiving station, so that the pressing of a key causes the corresponding sign to be printed. The polarized relay is shown in Fig. 19.

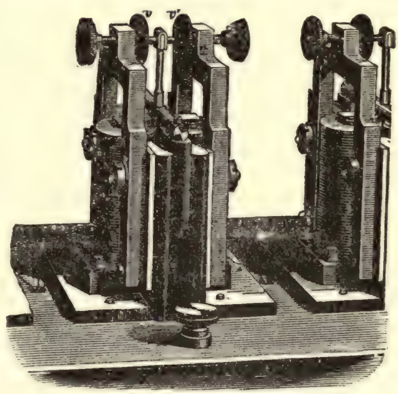


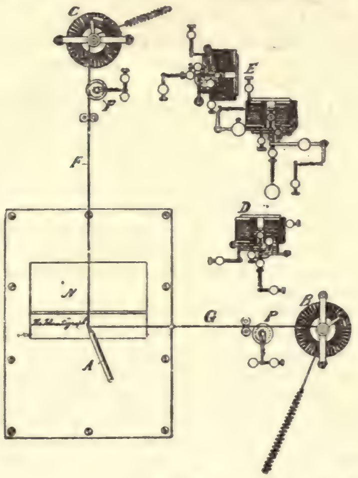
FIG. 19.—Relay.

A stenographic line corresponds to the depression of not more than 12 keys. The last of the relays is not connected to a printing electro, but to the electro-magnet $M\ M$, Fig. 18. The movement of the armature of the latter effects the movement of the roll of paper, so that after every revolution of the phonic wheel the paper is advanced a step, on receiving its imprint of signs. After each movement the instrument is in condition to receive another impression.

III. AUTOGRAPHIC TELEGRAPHS.—*The Gray Telautograph.*—This apparatus, invented by Prof. Elisha Gray, of Chicago, consists primarily of two instruments, a receiver and transmitter, each provided with a pen. The transmitting pen is connected to operate circuit making and breaking devices, termed "interrupters," located in two electric circuits and arranged to interrupt the currents passing over the respective circuits at short intervals, producing current pulsations as the pen is moved in two directions crosswise of each other in forming characters, the number of pulsations in the respective circuits being determined by the distance which the pen is moved in the respective directions. These two circuits pass through the receiver and include two pairs of "receiving magnets," the armatures of which act to impart a step-by-step movement to the receiving pen in two directions crosswise of each other, the number of steps in each direction being determined by the number of times the respective circuits are interrupted. By this means the movements of the transmitting pen in the two directions operate through the interruptions in the currents passing over the circuits to impart corresponding movements to the receiving pen, and thus reproduce the matter written by the operator.

The accompanying illustrations, Figs. 20 and 21, show respectively a general plan of the transmitter and receiver. The transmitting pen, A, is connected at its point to two cords or other flexible connections, $F\ G$, which extend horizontally at right angles to each other, and operate the two circuit making and breaking devices, $B\ C$, termed the "interrupters," located in the two main circuits, connected to B and C. The arrangement is such that as the pen, A, is moved from left to right and *vice versa*, the circuit of B is made and broken repeatedly in quick succession, producing pulsations therein, varying in number with the linear extent of the movement of the pen, and varying in speed of succession with the rapidity of such movement; while, as the pen is moved up and down in forming the characters, the circuit of C is interrupted and pulsations produced therein in the same manner.

The two interrupters, *B C*, are exactly similar in construction. Each of the cords, *F G*, is wound upon a small drum upon a shaft to which one wire of the circuit is connected. The shaft is provided with an arm, the end of which carries a brush which sweeps in contact with the face of a metallic disk, to which the other wire of the circuit is connected. The face of the disk over which the brush sweeps is provided with insulating strips, so that as the brush sweeps over the face of the disk in either direction the current passing over the circuit in which the brush and disk are located will be made and broken repeatedly in quick suc-



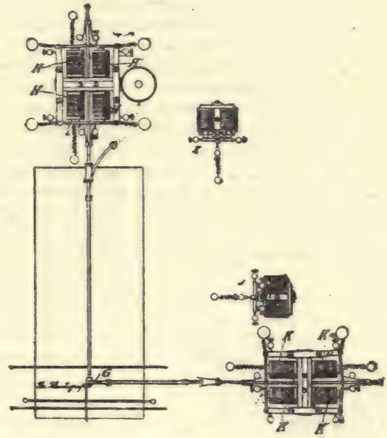


Fig. 20. Gray telautograph. Fig. 21.

cession. Each of the shafts is also provided with a second cord, which is wound upon the shaft in the direction the reverse of the cords, *F G*, and is connected to a spring which keeps the cords, *F* and *G*, taut at all times. Each of the cords passes between guides located between the pen and the shafts, and the cords are provided with stops which engage with the guides and arrest the cords and limit the movement given to the shafts and brushes.

The transmitting instrument is also provided with two local circuits, which include local batteries and a pair of pole changers, *D E*, which are located, respectively, in the main circuits of *B* and *C*, and which act to automatically change the polarity of the currents passing over the respective circuits whenever the movement of the transmitting pen in either direction is reversed.

The pole changers, *D E*, are connected to the two poles of the main batteries, and to the two wires of the respective main circuits, in the usual manner. For the purpose of operating the pole-changers, the cords, *F G*, pass around pulleys, *P P*, mounted upon shafts, which operate circuit makers and breakers, included in the respective local circuits. For this purpose the shafts are provided with arms, which are frictionally connected to the shafts, and have a limited movement between fixed stops. The arms, and one of the stops of each arm, are included in the respective local circuits, so that the rocking of the arms between their stops operates to make and break the local circuits, and thus operate the pole changers, *D E*, to change the polarity of the currents passing over the main circuits of *B* and *C* at each vibration of the arms.

It will now be readily understood that, as the pen makes the down strokes in forming the characters, the cord, *F*, will be unwound from the shaft of the interrupter, *C*, revolving the shaft, and moving the brush over the disk, and interrupting the current over that circuit repeatedly and in quick succession, the number and rapidity of the interruptions being determined by the speed and extent of the movement of the pen.

As the pen makes the upstrokes, the spring will rewind the cord, *F*, and move the brush in the reverse direction, interrupting the current in the same manner. It will also be understood that, as the pen moves upward, the cord, passing around the pulley, *P*, will close the local circuit of the pole changer, *E*, and send currents of one polarity over the line to *C;* and, as the pen moves downward, the pulley will open the circuit of the same pole changer, so as to send currents of opposite polarity over the same line.

What has just been said with regard to the *C* circuit also applies to the circuit of *B* when the pen is removed from right to left, the pole changer, *D*, being then operated by the lower pulley and arm, *B*, so as to change the polarity of the current, according as the motion is from left to right, or vice versa.

We now come to the operation of the receiving instrument, which is shown in Fig. 21. This consists of a pen, connected by means of a tube with a supply of ink, shown at the right, adjoining the upper receiving magnets. The pen is connected to two rods, which are placed at right angles to each other, similar to the cords in the transmitter, and are jointed, so as to have a free movement sidewise. One of these rods passes through the frame carrying the magnets, *H H*, which are included in the circuit of the interrupter, *C*, of the trans-

mitter, and are provided with armatures, which act upon the rod in such a manner as to impart a step-by-step movement to it in opposite directions, according as one or the other of the magnets is energized. The rod and the magnets, *H H'*, and their armatures, are so arranged that the rod passes between the adjacent ends of the two parts of each armature in such a manner that, when the two parts of either armature are moved toward each other, they will act first to grip the rod between them, and being then moved toward the magnet, they will carry the rod with them, and impart a corresponding movement to the pen, *G*.

In connection with the magnets, *H H*, there is a polarized relay, *I*, which is so arranged that when its armature is on one contact, due to a current coming over the line in a certain direction, it sends that current into the lower magnets, *H H;* but when a current of opposite polarity comes over the line, it is carried to the other stop, and the current is sent into the upper magnets, the lower magnets being then short-circuited.

Now, it will be readily seen that when the pen, *A*, at the transmitting station is moved upward, it sends current pulsations of one direction over the line. These are received by the relay, *I*, and sent into the lower magnets, *H H*, which act, as described above, to grip and raise the rod to correspond exactly with the number of pulsations, which, of course, are determined by the amount of movement given to the transmitting pen, *A*. When the latter is moved downward, the current impulses are sent in similar way into the upper magnets, which grip and lower the rod in an analogous manner at each pulsation. The identical action also takes place with the current transmitted over the main line, connected to the interrupter, *B*, the current passing into the relay, *I*, and magnets, *K K*, which act upon the rod at right angles to the first to move the pen sidewise in either direction.

From this it follows that any movement of the transmitting pen in any direction oblique to the line, or intermediate between these two directions, will cause the receiving pen to move in a corresponding direction, but with a compound movement made up of a number of steps taken at right angles to or crosswise of each other, the relative number of steps in each direction depending upon the obliquity of the direction in which the transmitting pen is moved. By this means the receiving pen is caused to substantially follow any movement of the transmitting pen, and thus reproduce a fac-simile of whatever is written or traced by the latter.

The Writing Telegraph.—This is the latest and most perfect form of the Cowper telegraph, and is being used in this country by the Writing Telegraph Co. with many radical improvements. The system consisted in the use of a transmitter, which served to vary the current on two lines connected to the receiver. The latter consisted of a pair of electro-magnets placed at right angles to each other, and acted upon an armature which followed exactly the movements of a stylus in the transmitter; this stylus served to vary the currents on the connecting lines by cutting in or out a set of resistances.

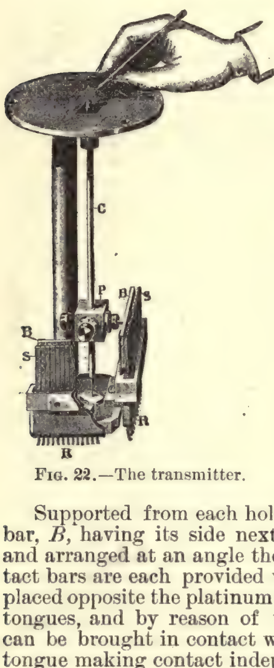


Fig. 22.—The transmitter.

The transmitter, which fully meets all the requirements for electric writing, is the invention of Mr. Harry Etheridge. This part of the apparatus, which is shown in perspective in Fig. 22, consists of a top plate, which rests on the top of the case. A rod depends from this plate and supports the base. Secured to this base, and arranged at right angles to each other, are two receptacles, in which two series of steel spring tongues, *S S*, are separately held in a vertical position by an insulating cement.

The spring tongues are placed in line with each other, edge to edge, with a sufficient space between them to avoid contact. They are also hardened and tempered so as to readily return to their normal position after pressure on them is released. To the lower end of these tongues a series of resistances, *R*, are secured, while their upper ends are provided with platinum contacts.

Supported from each holder by two spring strips, which are insulated, is a brass contact bar, *B*, having its side next to the steel tongues and arranged at an angle thereto. These two contact bars are each provided with a platinum wire placed opposite the platinum contacts of the spring tongues, and by reason of their spring supports can be brought in contact with the tongues, each tongue making contact independently of the rest.

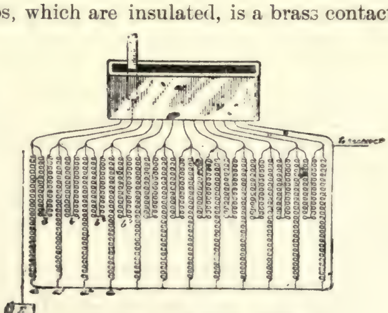


Fig. 23.—Resistance circuit.

The stylus rod, *C*, is screwed into the base, and its spring at the lower end allows of a free movement of the upper end in any direction. A pressure block, *P*, as shown, is secured to the stylus rod. Two adjustable pressure heads are screwed into this block, and held tightly by lock nuts in whatever position adjusted.

When the stylus is in its normal position, the pressure heads are so adjusted that contact is made with the projection on the contact bar, and the contact bar with the first spring tongue,

whereby any lost motion is prevented. When the stylus is operated, the contact bar is pressed against the tongues, making contact with a greater or less number, according to the extent of movement of the stylus, thus cutting in, or out, the resistances required to regulate the movement of the receiving pen. The resistances are arranged to avoid any break of circuit or oxidation at the contact points.

There are two series of resistances employed for each set of tongues, and both connected to them in the manner shown in Fig. 23. One, a, a^1, a^2, etc., is arranged in parallel arc; the other, b, b^1, b^2, etc., in series; and both combined. The resistance of a^1, measured in ohms, is the same resistance as b. The resistance of a^2 is less than the resistance of a^1, but is the same resistance as b^1, and so on; the resistance continuing to decrease from a maximum resistance arranged farthest from the receiver, to a minimum resistance; the last tongue to make contact with the contact bar controlling the lowest resistance.

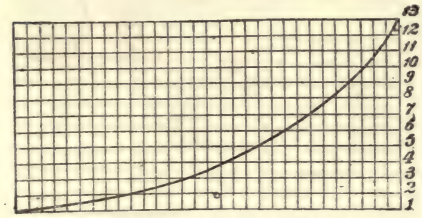


FIG. 24.—Curve of resistances.

The operation is as follows: When the tongues are out of contact with the contact bar, the current circulates in every branch, being, of course, proportional to the resistance. When, through the movement of the stylus, the contact bar touches tongue No. 2, the resistance, a^1, is placed in parallel arc with resistance, a, while the resistance, b, of resistance equal to a^1, is practically electrically cut out. The resistance, b, therefore, prevents an open circuit in a^1 when contact *2* breaks contact with the contact bar, balancing the resistance, a^1. In other words, the resistance, b, offers another and equivalent passage for the current the moment a^1 is separated from a, and so on throughout the remainder of the arrangement of resistances.

This transmitter has been used in commercial work with heavy battery for months, and has never required touching. It has been tried in every style of work expected of the system, and been found reliable.

Twelve contacts give all the variation required for any length of line. A parabolic curve (Fig. 24) describes the curve of resistances, and the same curve is used for all lines. The current used varies from a minimum of ·0165 to a maximum of ·03 of an ampere.

The receiver is shown in Fig. 25. The only adjusting screws about the apparatus are one for each magnet, and these raise or lower the cores to or from the armature, when being adjusted to the line. The double armature, magnetically connected, and the float employed to remove the tremor of the armature rod, are retained. There is an armature (not shown) under the cores of the magnets, which releases the paper-moving mechanism. Under the top plate of the transmitter are contacts which automatically cut out the transmitter when the stylus rod is released, and also a contact for calling up when placed in an exchange system.

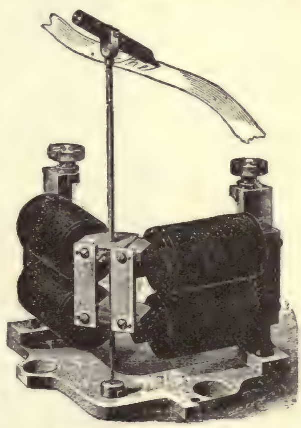


FIG. 25.—The receiver.

IV. FAC-SIMILE TELEGRAPHS. *The Glen-Melville Map Telegraph.*—Lieutenant Glen and Lieutenant-Colonel Melville, of the British army, have devised an ingenious system, by which the ordinary operation of telegraphing may be made to serve the purpose of reproducing sketches and plans. The method consists of either drawing the design to be transmitted on ruled paper, divided into little squares by vertical and horizontal lines, or laying a transparent paper, tracing cloth, or other transparent sheet, divided by lines into squares, over the drawing. The squares in each compartment, as shown in Fig. 26, are denoted, respectively, by pairs of letters, the alphabet running down the outer side for the horizontal rows of squares, and along the top for the squares in vertical series. A corresponding paper, which may be of a different scale if convenient, is kept at the receiving station. The operator at the transmitting station can thus indicate by alphabetical letters to the receiving station any point on the paper falling in the center of any of the squares; the person at the receiving station will apply his pencil to that point, and will then be directed to the next point, drawing a line with the pencil, and so on to form a complete outline drawing. The illustration, Fig. 27, shows two portraits; the one being the original, the other the transmitted copy. Patches of shading, of the several darker or lighter tints as shown in Fig. 28, may be put in by special directions, the transmitting signs for which must be preconcerted.

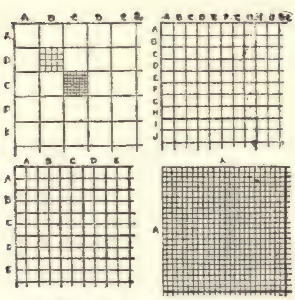


FIG. 26.—Map telegraph.

V. Printing Telegraphs. *The Essick Printing Telegraph.*—This is the invention of Mr. S. V. Essick, of New York, and is being operated by the Essick Printing Telegraph

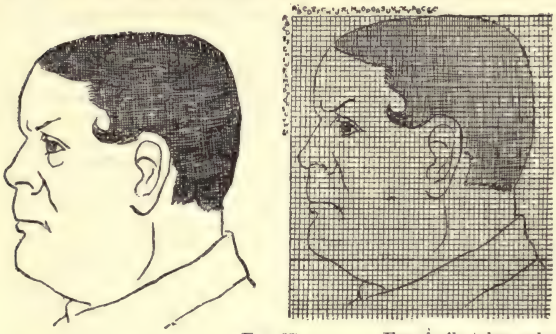


Fig. 27.

Fac-simile telegraphs (page 847).

Fig. 28.

Co. - Instead of employing the tape heretofore used a paper roll is employed having a width of 4½ in., upon which the letters are printed in lines the width of the roll, so that they can be read in the same manner as a page of ordinary print.

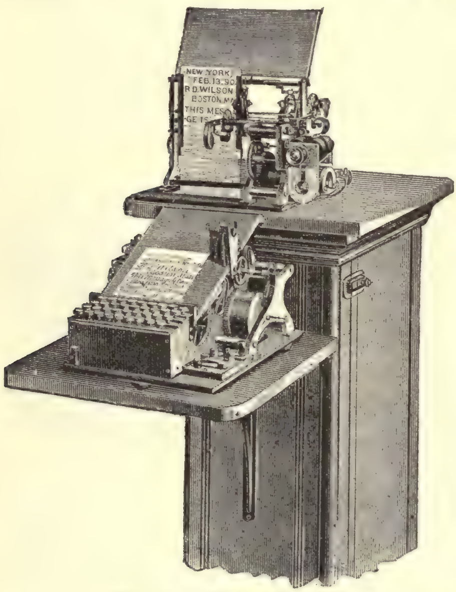


Fig. 29.—Printing telegraph.

The instrument, Fig. 29, consists of a receiver which is operated by impulses received from the line through a polarized relay which operates a type-wheel. Fourteen impulses represent the entire alphabet, making a complete revolution of the type-wheel, which is capable of turning 200 revolutions per minute, and by which it is claimed 50 words a minute can be printed. The roll of paper, which is continuous, is held in a frame which travels one space for each letter printed, and at the end of the line is automatically shifted back to the beginning of a new line, and at the same time advances the space dividing two lines. The impulses move the instrument, and operate at the same time all the other instruments on the line. Any break in the wire, therefore, opens the circuit, which entails the breaking of the communication, so that the operator immediately becomes aware of it. The system, it will be seen, is so arranged that the transmitting operator records the message, not only at the other end of the line, but also at his own instrument, so that there is constantly available a copy of all the messages sent. The duplicating of the order transmitted by the copy at the transmitting office is evidently a valuable feature in many departments, especially in railroad work, as it affords a check upon all orders transmitted.

VI. Train Telegraphy. *Phelps Induction Train Telegraph.*—The principle upon which the train telegraph system of Mr. Lucius J. Phelps is based is that of induction according to the law that if a current be sent through one of two parallel wires in close proximity to each other, the second wire (on closed circuit) will have a momentary current *induced* in it, the direction of which will be contrary to that of the primary or *inducing* current; while, if the primary current be interrupted, the induced current will be reversed, *i.e.*, flowing in the same direction as the primary current. By utilizing this oft-applied principle, therefore, electrical effects and currents are obtained *at a distance* from, and *without contact* with, any source of electricity. Thus, if in Fig. 30, a current be sent through the bottom wire *a*, a momentary current will be set up in the parallel coil, which current can be utilized to actuate a relay, and through it a sounder. While this particular employment of a reduced current to actuate a relay is not in itself new, its modification and adaptation is very ingenious. By referring

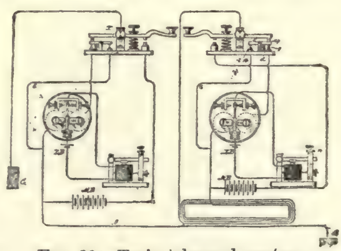


Fig. 30.—Train telegraph system.

also to the diagram, Fig. 30, the general arrangement of the sending and receiving stations will be seen, that to the right representing the moving car.

Taking the terminal station first, we find its principal equipment to consist simply of a main battery, a pole-changing key and a telephone, the latter taking the place of the relay and sounder shown in Fig. 30, and all connected in the usual way with the line wire.

In this system the line wire is run between the rails, and consists of an insulated copper wire laid in a covered trough composed of strips of wood hollowed out to receive the wire. Fig. 31 shows the manner in which the wire is secured and protected, the inclosing strips resting upon blocks secured to the cross-ties. The car equipped with this system differs from the ordinary car only in the addition of a pipe running below and along the centre of the car between the trucks, and hung by suspenders. This pipe is situated directly over the line wire, at a height of seven inches, and consists of a two-inch gas pipe. This pipe contains a $1\frac{1}{4}$-inch rubber hose, in which the induction wire of the car is incased. It consists of No. 14 copper wire, single braided and paraffined. One end of this is first drawn through the pipe, passed up to the ceiling at one end of the car, back to the other end, then down and into the pipe, and the operation is repeated until ninety convolutions are completed. This forms a continuous circuit about $1\frac{1}{2}$ miles in length, and presenting about $\frac{3}{4}$ of a mile of wire parallel with the main line wire upon the track. The circuit throughout is enclosed in a rubber hose, the object in carrying the return leads along the top of the car obviously being to separate, as far as possible, those portions of the wire in which the current flows in opposite directions.

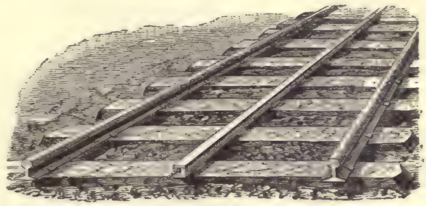


FIG. 31.—Phelps induction system.

The terminals of the wire so wound around the car are brought together and carried to a transmitting key placed on top of the small compartment situated in one corner of the baggage car, as shown in Fig. 32, which represents the moving telegraph station. The equipment of this station consists of a transmitting key, a "buzzer" or vibrator, a sounder, a polarized relay, and a battery of five quart cells, one of which constitutes the local battery. The terminals of the coil are carried to the key, and connect through the back contact of the latter with the polarized relay, shown in Fig. 33, the construction of which will be explained presently. This is the receiving instrument on the car, and closes the local battery circuit through the sounder, which is placed on a sounding-board supported by brackets above the relay. For the transmission of messages from the car, the current from the four cells is passed through the front contact of the key before mentioned, through the $1\frac{1}{2}$ miles of wire in the coil, and through the buzzer, which breaks the current very rapidly and converts the single "click" into a humming sound. This rapidly vibrating current induces similar currents in the main-line wire on the track, and the operator at the terminal station reads the Morse characters from a telephone, which reproduces the humming of the "buzzer." If it is desired to receive a message in the car, the operator at the terminal station merely manipulates his key in the usual way, and the pulsations of the current in the main line induce corresponding effects in the wire placed a few inches above it on the car. The induced currents actuate the delicate relay, and the sounder gives forth its signals in the same way as usual and can be easily heard at a distance of ten feet even above the din of a moving train.

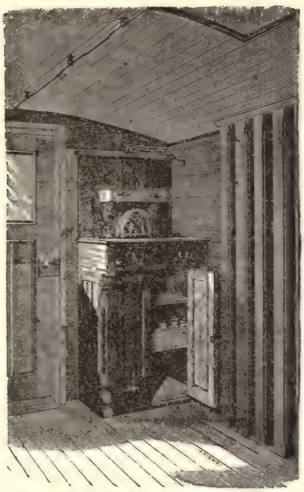


FIG. 32.—Train telegraph station.

It is evident that the terminal station might employ a relay and sounder in place of the telephone, but the latter is naturally the most convenient, as it requires only a small battery on board the train. Again, the telephone might, with equal facility, be employed as a receiver on board the train, but it was found that the noise which always accompanies a moving train prevented a distinct understanding of the signals. A relay was, therefore, necessary, the principal requirements of which were two-fold. In the first place a very delicate relay was required for the reception of the very weak induced currents; and secondly, one in which the armature should not be affected even by strong jarring and vibration, such as is experienced on trains. These antagonistic elements were, however, provided for in the

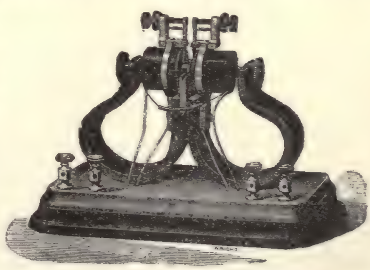


FIG. 33.—The relay.

relay designed by Mr. Phelps, and which is represented in Fig. 33. It will be seen to consist of two steel magnets, bent as shown, with their like poles brought together and carrying an extension piece which has a V-shaped groove at the top. The other ends of the magnets carry extension pole-pieces and fine wire helices. The armature is about the same thickness and size as a 3-cent nickel piece, but its lower edge is straight and thinned down to a knife edge, which rests in the bottom of the V-shaped groove. Thus we have friction entirely

FIG. 34.—Edison-Smith static train telegraph.

removed, while the small mass and leverage of the armature, together with the strong magnetic field in which it is placed, prevent its moving under shock or vibration. It responds, therefore, only to the impulses sent through the coils, and its action is very delicate in spite of its shock-resisting power.

Edison-Smith Static Train Telegraph.—While the Phelps train telegraph is actuated by dynamic induction, the Edison-Smith system is based upon static induction, the metal

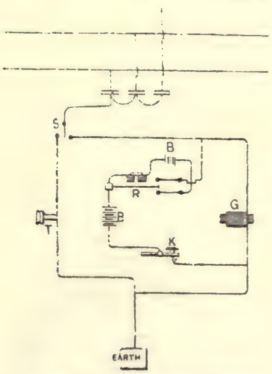


FIG. 35.—Station connections.

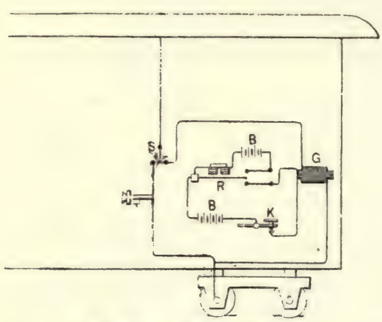


FIG. 36.—Car connections.

roofs of the cars being so charged that they act inductively upon the telegraph wires along the line, and thus render communication possible. In the same way the wires may act upon the roofs, and a message may be received on the train.

The arrangements of the car and the terminal station are quite simple and consist of a telephone receiver in lieu of a sounder, a Morse key, a vibrator, and an induction coil. Fig. 34 shows the operator seated at his desk, which has been installed in one of the passenger cars, and having two telephones to his ears while he receives a message.

The manner in which the messages are sent and received will appear quite plain upon reference to the diagrams, Fig. 35 and Fig. 36. The latter shows the apparatus as arranged on the car, and the former, that at the station; they do not differ materially from one another. Referring to Fig. 36, it will be seen that the metallic roof of the car is connected by wire to the switch *S*. When turned toward the left, the switch closes the circuit through the telephone, which is connected to the ground through the wheels of the car, and this is the position of the switch when a message is being received. When transmitting a message, however, the switch is turned to the right, which closes the circuit through the one end of the secondary of the induction coil *G*, the other end being grounded in the same way as mentioned above. The primary of the induction coil *G*, is joined to a Morse key *K*, and battery *B*, and interposed in the circuit is the vibrator *R*. When the switch *S* is turned, the vibrator is started, so that when the key is pressed the primary coil of *G* has a series of rapidly intermittent currents sent through it. The secondary of *G* being connected to the roof of the car, it consequently sends into the latter a series of rapidly intermittent charges of high potential. These react upon the telegraph wires and influence the condensers attached to the lines at the terminal station shown in Fig. 35. Here it will be noticed the condensers are coupled in parallel, one side of each being joined to a wire and the other to the leading-in wire. The rapidly alternating charges produced by the vibrator are received in the telephone as a series of "buzzes," or a musical note, the duration of which depends, of course, upon the length of time the key is pressed. In this way the dots and dashes are received as short and long notes.

TEMPERING AND HARDENING. *The Harvey Steel Hardening Process.*—In recent trials of steel armor plate by the United States Government it was found that plates, whether made of ordinary steel or of nickel steel, that had been treated by the Harvey hardening process, were superior in shot-resisting power to similar plates not so treated. (See Armor.) The details of this process are thus described in patents granted to the inventor, Mr. H. A. Harvey, of Orange, N. J.:

"The armor plate having been formed of the desired size and shape from a comparatively low steel, such as Bessemer steel or open-hearth steel, containing, say, 0·10 per cent. to 0·35 per cent. of carbon, is laid, preferably flatwise, upon a bed of finely powdered dry clay or sand, deposited upon the bottom of a fire-brick cell or compartment erected within the heating chamber of a suitable furnace. The plate may be so imbedded that its upper surface is in the same plane with the upper surface of those portions of the bed of clay or sand which adjoin the sides and ends of the plate, or the plate may, if desired, be allowed to project to a greater or less distance above the surface of the clay or sand. In either case the treating compartment is then partially filled up with granular carbonaceous material, which, having been rammed down upon the plate, is covered with a stratum of sand, upon which there is laid a covering of heavy fire bricks. The furnace is then raised to an intense heat, which is kept up for such a period of time as may be required for the absorption by the metal adjoining the upper surface of the plate of, say, an additional 1 per cent. (more or less) of carbon, or, in other words, the quantity of carbon, in addition to that originally present, which may be necessary to enable the said metal to acquire the capacity of hardening to the desired degree. The temperature of the heating chamber outside of the treating compartment is brought up to a height equal to or above that required to melt cast-iron, and is kept up for greater or less length of time, according to the depth of the stratum of steel which it is intended to charge with an excess of carbon. This period, however, will, of course, vary according to the efficiency of the furnace. As a general rule, the thicker the armor plate the greater will be the permissible depth of supercarburization. A 10½-in. plate and a depth of supercarburization of 3 in. are herein referred to merely for the purpose of illustration. After the conclusion of the carburizing treatment, the plate is taken out of the furnace, and without removal of the carbonaceous material from its surface, is allowed to cool down to the proper temperature for chilling. When it is seen that the supercarburized surface is so far cooled down as to have a dull cherry-red color, the carbonaceous material is quickly removed, and the plate is then chilled by being sprayed with torrents of cold fluid or by being submerged and kept in motion until cold in a large body of cooling fluid—as, for example, a more or less rapidly running stream or river of fresh water, or a tidal current of salt water. The exercise of this precaution insures the subsequent uniform hardening of the subcarburized surface of the plate."

Tempering steel axles.—A method of tempering steel car axles, by which it is claimed that their strength is increased and made uniform without at the same time making them brittle, and used by the Cambria Iron Co., of Johnstown, Pa., consists in heating the axle to a red heat, and plunging it into a trough filled with running cold water until the red heat visible on the surface is just about to disappear. On removing the car axle from the water the red heat returns to the surface, by conduction from the interior. The axle is then allowed to cool slowly in the air, thus partially annealing it.

Tempering steel in molten lead.—For many years it has been a somewhat common practice to use baths of the easily fusible metals or alloys for quenching steel, but it has recently been attempted on a large scale at the works of the Chatillon et Commentry Company, in France. An article on the process in use at these works was published in the *Iron Age* of October 10, 1889.

The following table of tests of water-quenched, oil-quenched, and lead-quenched bars is given by Henry M. Howe, in his work on *The Metallurgy of Steel*, as results obtained by the Chatillon et Commentry Company:

Properties of Steel annealed after Different Kinds of Heat-treatment—Chatillon et Commentry.

Number.	Per cent. of carbon, estimated.	Tensile strength, pounds per square inch, when annealed after				Elastic limit, pounds per square inch, when annealed after				Elongation, per cent. in 8 inches, when annealed after			
		forging.	quenching in water.	quenching in oil.	quenching in lead.	forging.	quenching in water.	quenching in oil.	quenching in lead	forging.	quenching in water.	quenching in oil.	quenching in lead.
1	0·10	44,090	51,628	....	....	26,170	35,130	....	....	30	20	....	....
2	0·20	43,379	64,429	48,499	44,375	25,601	48,357	36,979	26,738	34	28	30	31
3	0·30	65.567	80,785	71,256	72,251	36,979	52,340	41,815	43,806	24	21	24	22
4	0·40	70,402	88,039	81,496	74,100	39,112	59,024	53,477	45,939	20	18	22	21
5	0·50	77,941	105,391	98,706	86,190	43,806	72,251	65,567	51,486	21	15	19·5	20·5
6	0·60	85,336	112,360	102,404	89,603	46,935	81,070	70,402	53,193	18	13	17	17
7	0·70	91,026	126,583	113,782	99,559	52,624	88,181	73,958	61,158	16	14	14	16
8	0·80	93,870	137,961	119,472	106,671	54,046	92,448	76,803	56,891	17	11	13	14
9	0·90	98,137	140,806	123,739	108,093	54,046	93,870	79,647	64,002	16	10	13	15
10	1·00	106.671	153,606	129,428	115,205	55,469	106,671	81,070	69,691	17	10·5	11	15
11	1·10	113,782	163,562	145,072	129,428	56,891	116,627	92,448	79,647	14	7	9·5	12
12	1·20	122,316	170,674	163,562	150,761	64,002	128,005	115,205	98,137	12	8	9	10
13	1·30	128,005	180,629	163,562	156,451	69,691	125,161	116,627	95,292	10	6	9	10

Thirteen sets of $1\frac{1}{8}$-in. square steel bars, apparently 8 in. long between marks, each set being of constant composition, are tested tensilely in four different conditions. These conditions are as follows:

(1) Simply annealed, apparently by slow cooling from dull redness after previous forging.

(2) Quenched in cold water from about a low yellow heat, then reheated to 750° F. (400° C.) and cooled slowly.

(3) The same, except that they are quenched in oil instead of water.

(4) The same, except that they are quenched in molten lead instead of water.

The proportion of carbon is approximately that given in the second column, and but little silicon, manganese, etc , is present—*i.e.*, the metal is true carbon steel.

Tempering Wheel: see Clay-working Machines.

TENONING MACHINES. Tenons may be made entirely with saws, or entirely with rotating cutters, or with a combination of both. Where cutters are used, one head may be made to cut a single, a double, or a treble tenon entire, at one operation. Where saws are used it is always necessary to have two sets. To cut a tenon with one cutter necessitates that the stick and the cutter-head shall have relative motion to each other parallel to the plane of the cheek of the tenon ; the cutter projecting over the stick to an extent equal to the desired length of tenon. This motion of the stick or of the cutter-head in a plane parallel with the cheek of the tenon will, if the cutter has the proper outline, cut both cheeks, both shoulders, and the end of the tenon.

By the use of a single cutter having a central tongue projecting beyond the rest, there may be made a double tenon having no shoulders on the outside, but having any desired amount of shoulder between the two tongues.

Where two cutter-heads are used, their axes are parallel with the length of the stick, and the latter is fed in a direction at right angles to its own length and to that of the cutter mandrels. Each of these cutter-heads is practically making a gain or kerf, which has only one side, the side kerf making the shoulder of the tenon. The distance between the cutter-heads determines the thickness of the tenon ; the height of the stick with respect to that of the mandrels, the shoulders. By raising the stick, or both the heads together, the shoulders may be made of the same width, or one wider than the other, with a fixed thickness of tenon. By keeping the stick in a plane parallel to those of the cutter-heads, but inclining it so that its length is inclined to those of the cutter mandrels, there may be made a tenon having a bevel shoulder ; but the end will be square with the timber, as for ordinary use, unless the cutters are arranged one in advance of the other, and one of their mandrels bears a cutting-off disk ; in which case there may be made a tenon having both the shoulder and the end beveled to the stick, but parallel to each other.

Tenoning machines producing their work by the action of cutters which remove chips have the advantage of doing work that is smooth in surface and of great accuracy in dimensions, but they consume more power than those which operate by saws. To cut tenons with saws there are required, to produce one double-shouldered tenon at one operation, two parallel mandrels, each bearing a cross-cut saw, and one bearing two ripping saws, the latter mandrel at right angles to the former two and to the stick. To make a tenon with

square shoulders, the stick is fed in crosswise, while lying parallel to the mandrel bearing the cross-cut saws, the stick being parallel to them. To produce a double shoulder, it must be fed in askew. The power required to remove two blocks of wood by four saw-cuts is for tenons even of the ordinary width of shoulder less than that needed to cut up into chips the material of the same blocks ; and the advantage in favor of the sawing system increases with the width of shoulder. But it is evident that double tenons cannot be cut with circular saws alone. To mount upon the same mandrel with the ripping saws, a grooving saw, so-called, would accomplish the desired result in the same machine, but of course the grooving saw, so-called, is not really a saw, as it performs its work by the utter destruction of the material removed, instead of by taking it out in bulk, with only the kerf as the waste.

I. Horizontal Tenoning Machines.—*The Fay Tenoning Machines.*—In older forms of tenoning machines the stick is placed parallel with the axes of the cutters, and there are two mandrels, one working the material away from the upper, and the other from the lower, surface of the stick ; each set of cutters working from one side to the other of the piece. In one machine for heavy work, the frame carrying the cutters traverses across the stick ; in another, for light work, the cutters have no traverse, and the stick or other piece to be tenoned is moved at right angles to the cutter mandrels and to the plane containing them. Such a machine can make only single tenons. In the one shown in Fig. 1, the same features are preserved, of two parallel mandrels, one above the other, and each bearing cutters which work their way through the material from one side to the other ; but for double tenoning the material is cut away from the tenon left by the other cutters, by a separate cutter-head rotating on a vertical axis. The vertical position of this cutter-head may be varied to suit the thickness of tenon. In this machine the work is fed across the cutters, the table having friction rollers running on planed ways, arranged to retain the table and keep it at a constant right line with the line of the heads. There are steps and gauges

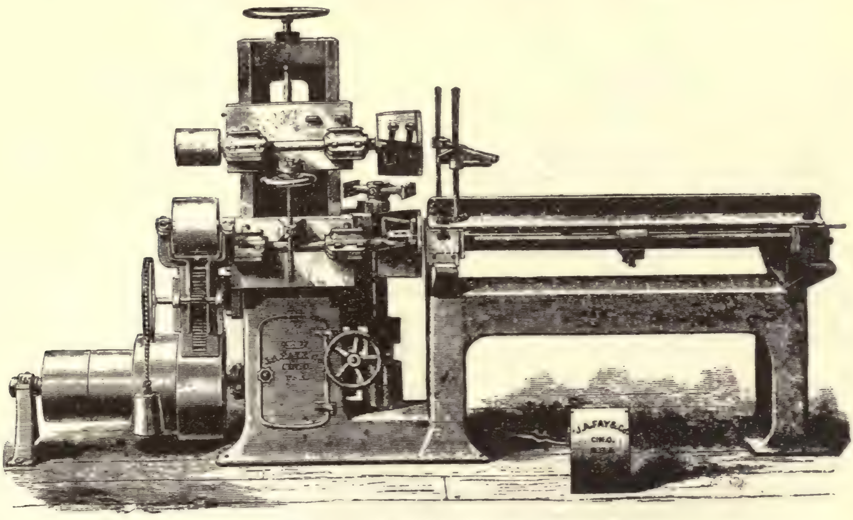


Fig. 1.—The Fay tenoning machine.

which can be set to suit pieces of various lengths, and an adjustable fence and road for holding the timbers in position. The heads have an adjustment for making the shoulder perfectly square, or out of square, as desired. This machine is for car work.

A development of this machine, shown in Fig. 2, is called a gap-tenoning machine, and has the peculiarity that its frame, between the table and the standard bearing the cutter-heads, has a deep gap for the passage of timbers endwise between the cutter-heads. By the application of a gaining head on the top spindle, it will do over-gaining ; and by placing a gainer on the lower spindle will do under-gaining on the ends. By taking off the lower cutter-head and putting on a circular saw it will do heavy cutting off. In this machine the carriage is self-acting, being driven by a screw worked by friction gears, the pressure of a lever causing it to travel in either direction or stopping it. For short work the power feed may be disengaged so that the feed may be by hand.

The Rogers Tenoning Machine.—Fig. 3, a car tenoning and gaining machine, made by C. B. Rogers & Co. for the heaviest class of work, and brought out within the past two years, is of the class taking in the timber horizontally and cutting tenons upon its ends by rotating cutters, the timber being fed cross-wise. The lower head can be run below the carriage so that the upper head can be used for cutting relishes upon the end of the timber ; the upper head, which is also on a horizontal axis, can be raised, and the lower one used for the same purpose, if desired. There is a third head, which is upon a vertical axis, carrying a throating

cutter for making double tenons. In working with this machine, the timber is placed on the carriage, which moves on rollers, and is passed between the tenoning heads, thus cutting one thick tenon ; it then goes on, and is brought into contact with the cutter-head upon the vertical shaft, which passes through the center, taking out a space according to the thickness

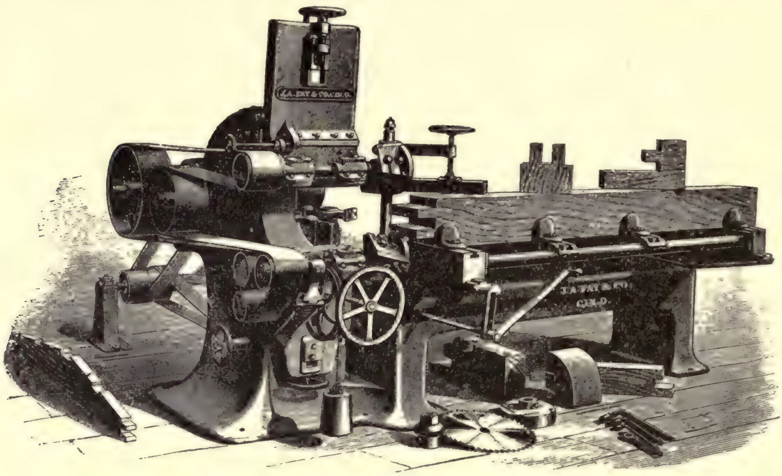


Fig. 2.—Gap-tenoning machine.

of cutter used, which completes the double tenon. There is a special attachment, independent of the tenoning part of the machine, for cutting gains, operating upon the under side of the timber, which is placed on the carriage and passed over the head. There is used an expanding head, that will cut from $\frac{1}{8}$ to 3 in. deep and from 2 to 4 in. wide. The countershaft that drives the vertical shaft and the gaining head is a part of

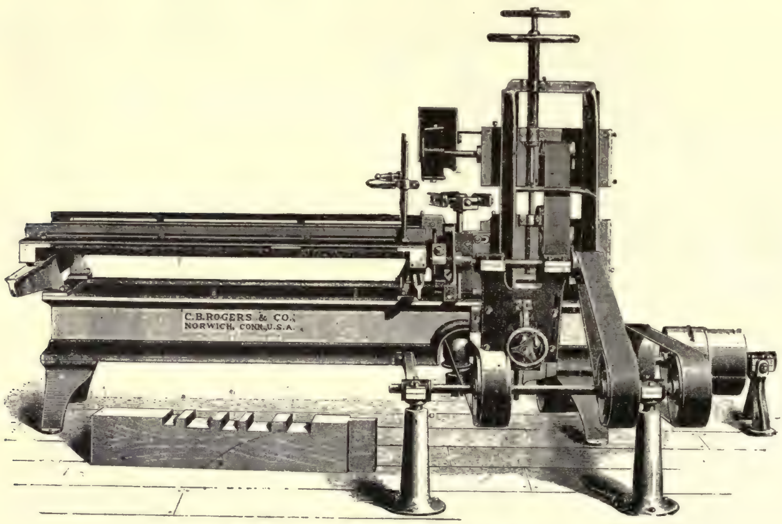


Fig. 3.—The Rogers tenoning machine.

the machine. When it is used as a gaining machine, it is worked from the back ; when used as a tenoning machine, from the front ; when it is being used as a gaining machine, the tenoning part is made idle simply by casting off the belt ; and the same way with the gainer head when the tenoner is in use.

The Egan Co.'s Tenoner Machine will make tenons on both ends of a stick at once, besides which, instead of making the tenons by the cutter-heads rather too long, and then cutting them off to the desired length, thus leaving a burr or ridge, it first cuts the stick to the proper length, and thus makes and finishes the tenons, leaving them with a smooth end finish.

In this machine, shown in Fig. 4, there is a bed like an ordinary lathe-bed, and bearing on the left-hand end a fixed, and on the right-hand end a laterally adjustable, housing, each housing carrying two pairs of cutters, on parallel horizontal axes which lie in the same horizontal plane. The front cutter-head in each housing bears a cutting-off saw; the back one, two sets of cutters, one for making each side of a tenon. A hand wheel at the right of the machine regulates the lengthwise distance between the housings and between their cutter-heads to suit the length of stock to be worked. The feed is across the machine, the stock being fed crosswise, and it is effected by sprocket chains along the face of each housing, each chain bearing dogs, the distance between which is adjustable to suit the width of the stock being tenoned. The material is fed away from the operator, and passing under the saws is cut to length; then passing between the back cutters, has both sides of both tenons worked on it. Pressure bars over the endless beds, or feed chains, keep the stock down on the latter while it is being cut by the saws and the cutters. These cutter bars will hold the stock down, even if one end is thicker than the other. The feed, which is automatic in its operation, is driven from a countershaft under the bed, and is controlled by a lever handy to the operator. Suitable provision is made for varying the angle of the cut and the length of the tenon. Each mandrel and slide has separate adjustment up and down on the housings, to suit the thickness of the tenon; and the upper mandrels have also side adjustment, to allow a tenon to be cut longer on one side than on the other, if necessary. There are four changes of feed.

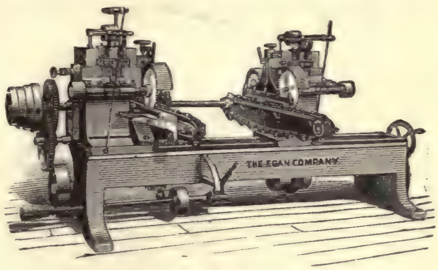


Fig. 4.—The Egan tenoner machine.

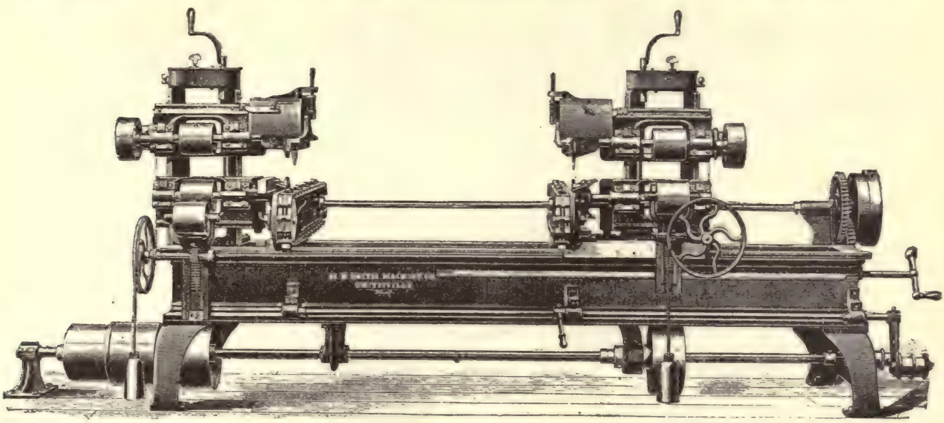


Fig. 5.—Double hand-tenoning machine.

The H. B. Smith Co. Double Hand-tenoning Machine, shown in Fig. 5, has a bed much like an ordinary lathe. At one end is a fixed column, bearing upper and lower cutter-heads on horizontal axes. At the other end is a sliding column, bearing similar cutter-spindles. A horizontal shaft, running the length of the machine, drives the cross-feed works, which are endless sprocket chains with projections, carrying the stick—which is presented parallel with the machine—across it and between the two cutter-heads on each end of the machine. Each of these cutter-heads has vertical adjustment independently of the others, so that single tenons may be cut on both ends of the stick at the same time, but varying in thickness and in position on the end of the stick. The feed chain is grooved to receive small angle plates, which, being adjustable in distance apart, may be removed or set to any width of stock. Over the feed are pressure bars, which are adjustable independently of the head, and held so as to support narrow stuff which may vary slightly in thickness. These pressure bars hold the stock down to the angle plates on the feed chain. In front on the left is an adjustable fence against which to support the lumber, so that pieces very close to length may be worked. The rate of feed is about 12 ft. per minute.

In hand-tenoning machines the work is sometimes done by cutters like those of rebating planes, cutting across the stuff, each time taking a shaving from the full width of the stick, and each time leaving a clean, smooth cut, so that at any point at which the cutting is stopped the work is left clean and smooth. Of course, in such work as this it is desirable to take as heavy cuts as possible until the required amount has nearly been cut away, when the thickness of shaving may be reduced in the interest of accuracy of dimension and smoothness

of cut. The power to work these plane tenoning machines may be greatly increased by the use of rack and pinion gears. It is seldom that the foot is used in driving such machinery, the arm being more delicate as regards the adjustment.

II. VERTICAL TENONING MACHINES.—*The Fay Car-tenoning Machine*, shown in Fig. 6, is for completing the tenon on large timbers for car work without reversal; and it will cut single, double, or triple tenons on both ends of long timber from one face without turning it end for end. This is done by a machine which presents the stick at right angles to two cutter mandrels and to the plane which contains them, but in this case the saddle containing the cutter-heads has a vertical traverse, and the tenon is vertical instead of horizontal. There are two tables, one before and the other back of the part bearing the cutter-saddle, and the stick is first clamped to the one before the cutters; the heads traverse down, cutting the tenon on one end; then the stick is shifted lengthwise to the table back of the cutters, and the heads traverse up, cutting the tenon on the other end of the stick. There is an adjustable fence for the thickness of the shoulder on the face side of the timber, and suitable gauges determine the length of the tenons. The head and attached moving parts are counterbalanced.

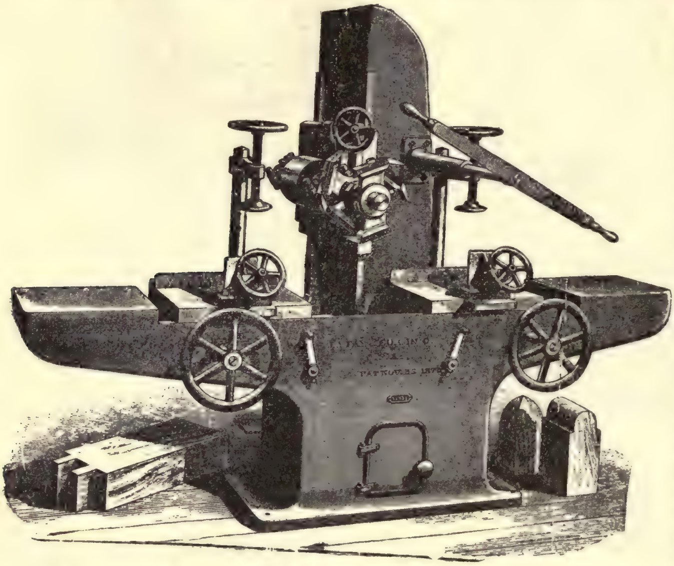


FIG. 6.—The Fay car-tenoning machine.

The Rogers Car-tenoning Machine, to cut double tenons, Fig. 7, is for work up to 16 in. square. There is a table on which the timber is laid, and that holds the timber in place by clamps, which are set by cranks in front. The bed adjusts to and from the double column of the machine by screws at the base, and has a movable section each side of the cutter-head for end adjustment of the timber to the cutters. The cutters are borne on a horizontal axis passing between the two columns at the back of the machine, and bolted from the back. The saddle carrying the cutter-head, which is counterbalanced, is raised and lowered by a large hand wheel. Hand wheels in front move the timber endwise, so as to bring the proper part of its length in contact with the cutters. The head is brought down, cutting as it goes, and passing into a recess in the table; then the timber is shifted lengthwise, and the head on the upward movement cuts the opposite end. There is a gauge by which the work may be set. The power stated as necessary to drive the machine is 8-horse, applied by an 8-in. belt.

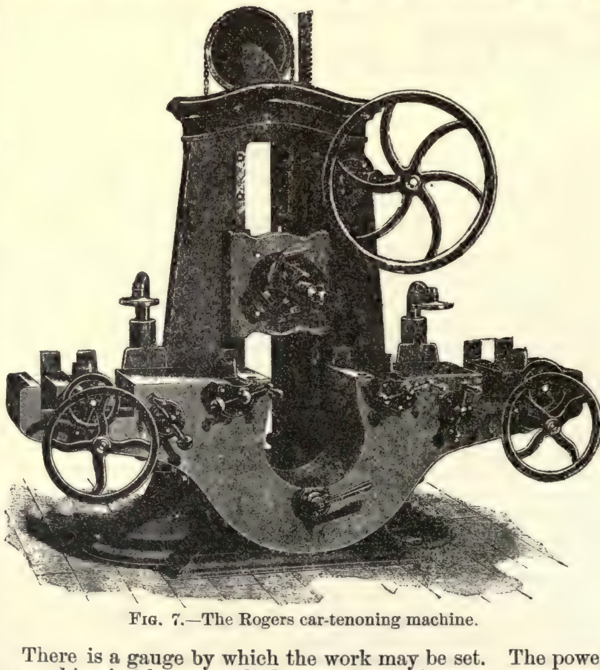


FIG. 7.—The Rogers car-tenoning machine.

A tenoning attachment, Fig. 8, for a vertical mortising machine, which works by chisels only, and not by boring, consists of a stock bearing a clamp, between the blades of which two chisels are held by their ends, their distance apart being regulated by a scale upon the clamp. This tool, used in a mortising machine, will cut tenons from one-eighth to one inch thick, three inches deep, and should prove useful for making window and door-screen frames, and for all light tenoning. The cutters may be adjusted together to form one wide cutter for cornering and shaping shingles in the same machine.

Fig. 8.—Tenon cutter.

Other Forms of Tenoning Machines.—*Blind-slat Tenoning Machines.*—In the blind-slat tenoning machine shown in Fig. 9 the tenons are produced by saw-like cutters borne on a horizontal mandrel, which is parallel with the slat. The slat is fed in to a stop-gauge through a rotating chuck, and then brought down upon the rotating cutter, which cuts and divides two tenons at once with one cutter-head at one operation. As the slat rotates, a cylindrical form is given to the tenon, and the latter is central in the width of the slat. The cut being made from the outside to the center, tearing or splitting of the wood is done away with. Releasing the table stops the chucks, and allows the slat to be fed forward to the gauge.

The slat tenoner shown in Fig. 10, and made by Rowley & Hermance, has a self-centering device for holding the slats, thus making a tenon in the center of the slat width, although, if desired, it may be made nearer one edge than the other. The slat is firmly held when being cut, and is not released until the tenon has been fitted and the slat cut off. The slat is moved to the saws, and two tenons cut by one motion of the lever. There is a stop to determine the length of the slats.

A self-feed blind-slat tenoning machine, made by the H. B. Smith Machine Co., has a vertical iron column bearing at its upper end a rotating gear-wheel, through the center of which the blind slat is fed. The slat is passed, while rotating, by a tenoning saw, which works away the stock so as to leave a cylindrical tenon in the center of width and thickness of the slat, the slat going on until it strikes a rear stop, which may be adjusted to make any length of slat desirable up to 17 in. There is a front guide stop by which the full length of stock may be gauged in length and tenoned ; so that if either the stock or the last piece is short, the piece may be turned about and gauged from the front; and if the piece is too short to handle, a plunger on the front stop will push it within the jaws of the clamp, thus preventing waste from inability to feed short pieces. The stock is unclamped on the delivering side of the machine or saws, doing away with the liability of two clamps getting out of alignment and doing inaccurate work, or of the finished piece getting caught against the stops. The clamp, which will hold stock of any length, rotates by power, coming in contact with a spring stop each round, where it remains in position until released by raising or lowering the hand lever, which moves the saws to or from the slat in the act of making or dividing the tenon. When this lever is released, the saws automatically resume a position which leaves the clamp with the slat central, so that when the slat is pushed forward it cannot come in contact with the saws.

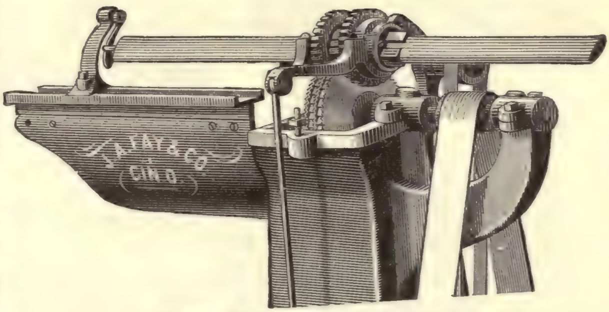


Fig. 9.—Blind-slat tenoning machine.

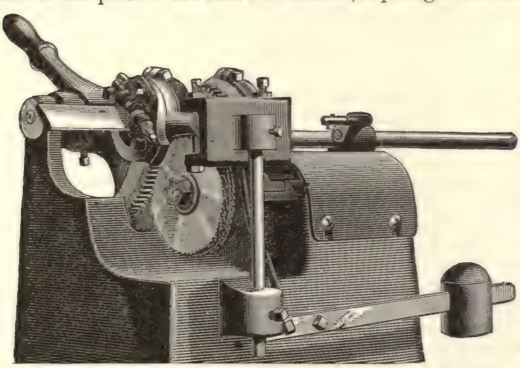


Fig. 10.—Slat tenoner.

Dovetailing machines, which are really tenoners, are of several classes. In the most common, the cutter is of the ordinary fly type, cutting with its side and end, and producing both the mortise and the tenon. In some of these, for work in drawer fronts and similar pieces, the cutting tools are in sliding frames, adjustable for the length of the pin or tenon ; the carriage bearing the material is moved vertically and lengthwise, automatically, cutting at each movement of the crank wheel a pin and a recess, cutting and feeding in both directions. The material is supported by a comb-like arrangement, between the teeth of which the cutters pass to their work. This being a species of tenoning which demands

special treatment, one of the machines for effecting a class of work which may be classed as dovetailing, and in some senses as tenoning, will be found described under the head of DOVETAILING.

TERRA COTTA LUMBER is the trade mark by usage and commercial name given to a composition of kaolinic clays and sawdust, in such proportions that, when the latter is burned out in the firing process, the brick residue is sufficiently porous or cellular to be profitably worked with carpenters' tools, constituting, in fact, a lumber indestructible by fire or age, and suitable to be used wherever pieces of not greater length than 2 or 3 ft. or less thickness than 1 in. can be employed. It is made up in various cellular shapes for building purposes, as shown in Fig. 1.

A large variety of porous earthenwares are now manufactured for structural uses. A

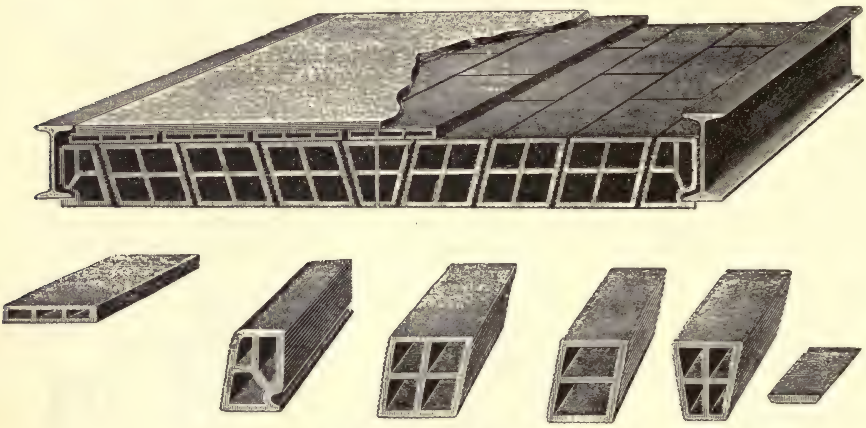


FIG. 1.—Terra cotta lumber.

comprehensive account of these will be found in a paper delivered by Mr. C. C. Gilman, before the Illinois Brick and Tile Association, at its convention, January, 1891. See *Scientific American Supplement* for May 30, 1891.

Tests of Engines: see articles under Engines. **Of Brakes**: see Brakes. **Of Pumps**: see Pumps, Reciprocating. **Of Boilers**: see Boilers, Steam. **Of Rope**: see Rope-making Machines. **Of Emery Wheels**: see Grinding, Emery. **Of Ice Machines**: see Ice-making Machines. **Of Locomotives**: see Locomotives. **Of Water Wheels**: see Water Wheels.

Threading Tools: see Tool Cutter, Lathe Tools, and Pipe Cutting.

THRESHING MACHINES. Threshers (colloquially "separators," because of the added duty of removing straw, chaff, and, to a great extent, grass seeds, weed seeds, and kernels of grain different in kind from the crop threshed) have remained for many years unchanged in main principles, but have far greater capacity and efficiency than formerly, and have some novel features added.

Fig. 1 is a representative improved American thresher and supplemental high stacker, made by Russell & Co., shown ready for work, the machine here represented traveling on the road by the locomotive power of the farm steam-engine used to furnish power when threshing. Specialist threshermen thus move the outfit from farm to farm, and thresh under contract for a fixed charge per bushel. For the interior arrangement of the same thresher see Fig. 2. It has, just beyond the threshing cylinder, a novel distributing "beater," consisting of a central tube with radial flanges arranged in spirals reversed from the middle circumference of the tube toward either end (Fig. 3). As the beater revolves, the central beaks of the flanges strike into the flying mass shot from the cylinder and distribute it the full width of the machine. The prominence of the flanges is so modified as they approach the sides of the machine as to equalize distribution and cause immediate separation to begin. This spiral beater is supplemented by the ordinary four-winged beater to whip the straw open, from which the mass of straw and grain falls upon the picker table, and then upon a series of lifting fingers to lightly toss it with a fan-like motion, imparted by rock shafts. The throw of the fingers is adjustable to suit the condition of the material threshed. Beyond these fingers is a series of connected alternating open pickers, with a tedder action, passing the straw onward while the kernels drop between them. Over the picker tail the straw falls 15 in. upon the extension table, which has a vertical motion at the first or lower end, and a vibrating motion at the other end, raising the straw on saw-tooth edges, but urging the grain kernels in, backward, down its inclined floor. Meanwhile a drag-up chain-elevator-way captures and returns to the threshing cylinder, up along the outside of machine, any incompletely threshed ears, to be rethreshed. To improve the cylinder spikes and enable them to stand the work of the high-speed machines of the day, a steel poll is welded upon a basis of tough iron (Fig. 4), greatly increasing the wearing quality of the tip

of the spike without rendering its shank liable to snap. A stacker propels the straw and chaff up the incline of its floor by traveling slats of wood with their ends secured to a pair of moving belts. The stacker, though driven by belt from the thresher, is mounted independently on its carriage, and can be folded for transport (Fig. 5). In operation it swings slowly from side to side on a pivot on its carriage, by a self-reversing gear, and forms a lunette-shaped stack (Fig. 6). The delivery end of the stacker can be raised gradually, as the stack grows, by means of a cross-shaft, central under the carriage, engaging an upright screw at each end. The driving power from the thresher can be diverted by a shifter-lever to actuate either the raising screws or the conveyor. To maintain a uniform delivery distance, and build the stack plumb, it is necessary for the outer end of the stacker to rise vertically, and this is accomplished by a link movement of the two posts supporting the heel of the stacker, which is designed to deliver straw up to as high as 23 ft. above ground level.

The Pitts (Buffalo, N. Y.) thresher has the right-and-left, spirally-flanged, transverse revolving distributor marked *D*, in Fig. 7. The card rack (above and beyond the ordinary beater, here marked *C*) stops access of straw to the distributor, but permits the large proportion of hulled kernels always shot over the beater by the whirling cylinder to fall into the distributor and be moved by it at once along an iron trough, *B*, to either side of the machine, and drop upon the grain-belt cells, where they are sure to be unoccupied by straw and chaff. This portion of the grain, always a large part, is, therefore preserved separate, instead of needlessly mingling with straw only to be sifted from it.

Fig. 8 is a bagger attachment on the "Minnesota" thresher, consisting of an erect revolving drum, with four half-bushel compartments to receive the cleaned grain from a cup elevator. As each half bushel of grain is passed into the bag, it is automatically tallied. In the Nichols-Shepard thresher, two gangs of vibrators are used, comprising five vibrating shakers. The first two and last three are repectively connected. While the duplex gang is moved backward and downward, the triplex gang is moved forward and upward, to pull the straw apart transversely about midway of its course through the machine, to facilitate separation. The counter-motions of the two shaker gangs are so proportioned as to steady the whole machine while running.

Fig. 9, interior of the Huber thresher, presents a novel and effective arrangement. The "beater" is placed low in the machine, and revolved with moderate speed near to and in reverse direction of the cylinder rotation. The effect is to lift the straw on the edges of the beater-flanges and receive loose kernels in the angular spaces between the beater wings, and allow them to slide downward upon the grain pan at the very outset of the career of the threshed material. The other features of this thresher are comprehensible in the figure without verbal description.

Automatic Feeder for Threshers.—Anderson's automatic band cutter and feeder, Figs. 10 and 11, is an attachment for threshing machines to cut the bands of the sheaves and feed the grain evenly, by maintaining a steady delivery of it to the thresher cylinder. Only very

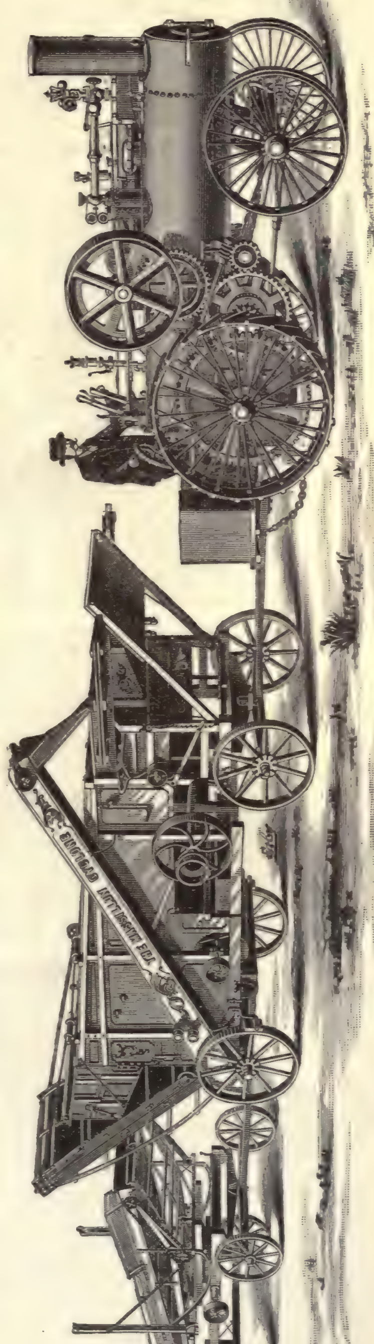


FIG. 1.—Thresher and stacker.

expert operators can do this by hand, and the labor is onerous, and usually very trying to

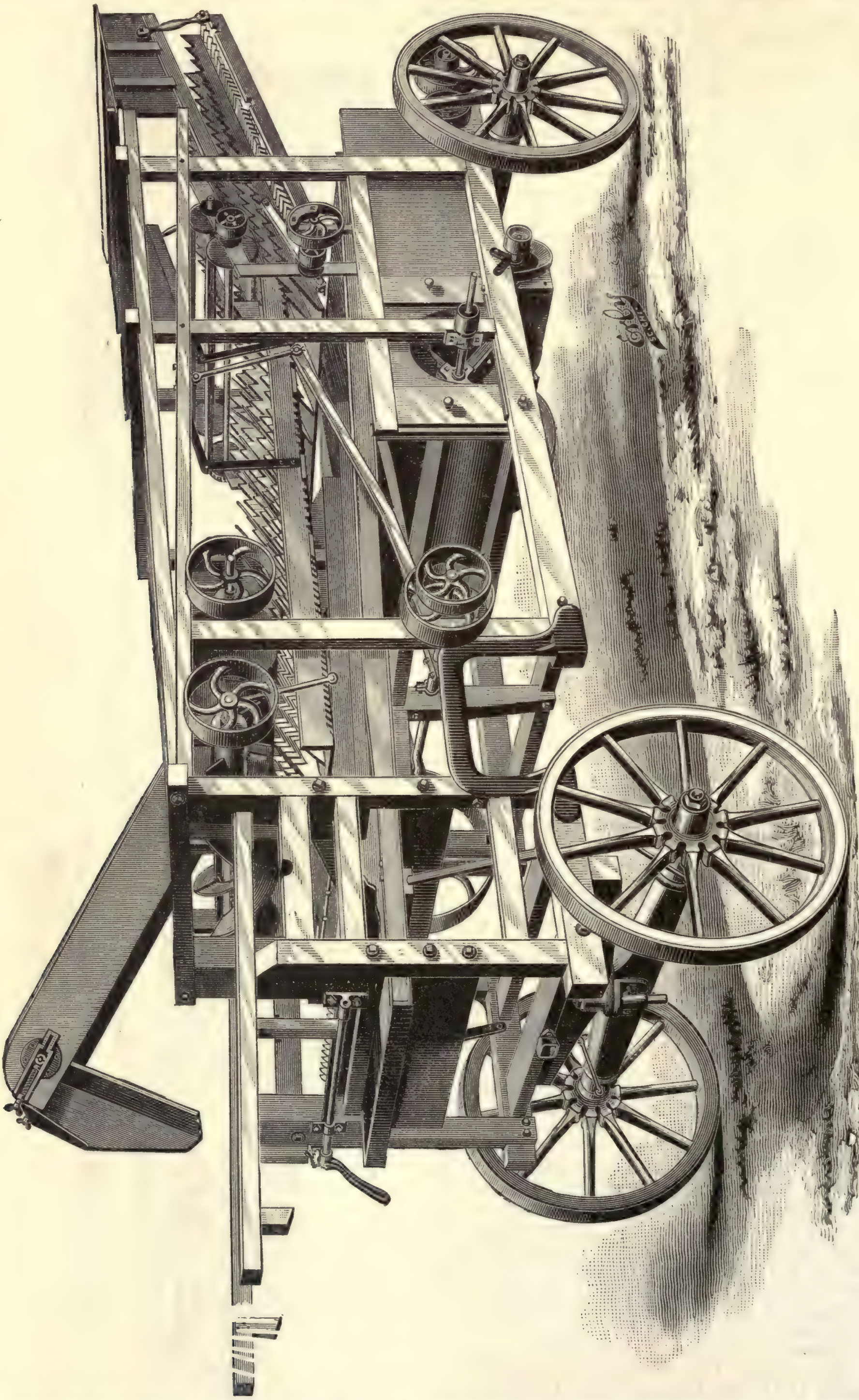


Fig. 2.—Thresher.

throat and lungs by reason of the fine dust which is thrown out from the machine ; an assistant is also required to stand by and cut the bands of the sheaves, and his position is danger-

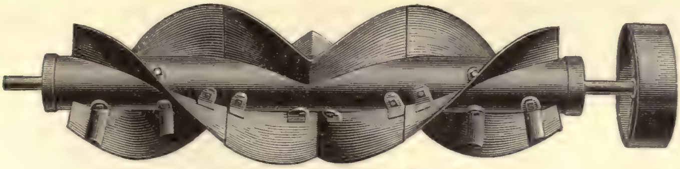


Fig. 3.—Spiral beater.

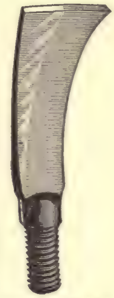


Fig. 4.—Spike.

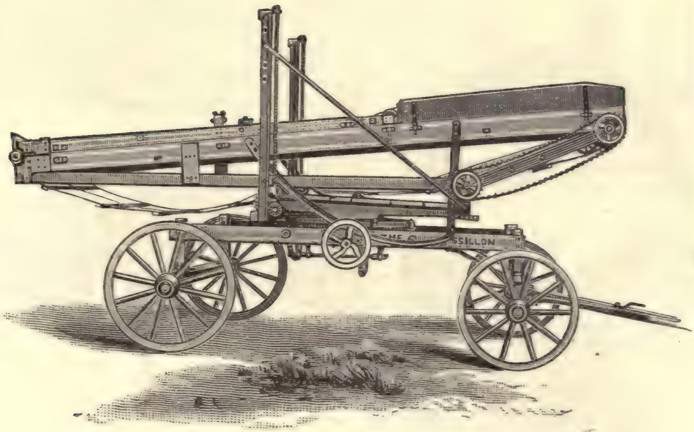


Fig. 5.—Stacker.

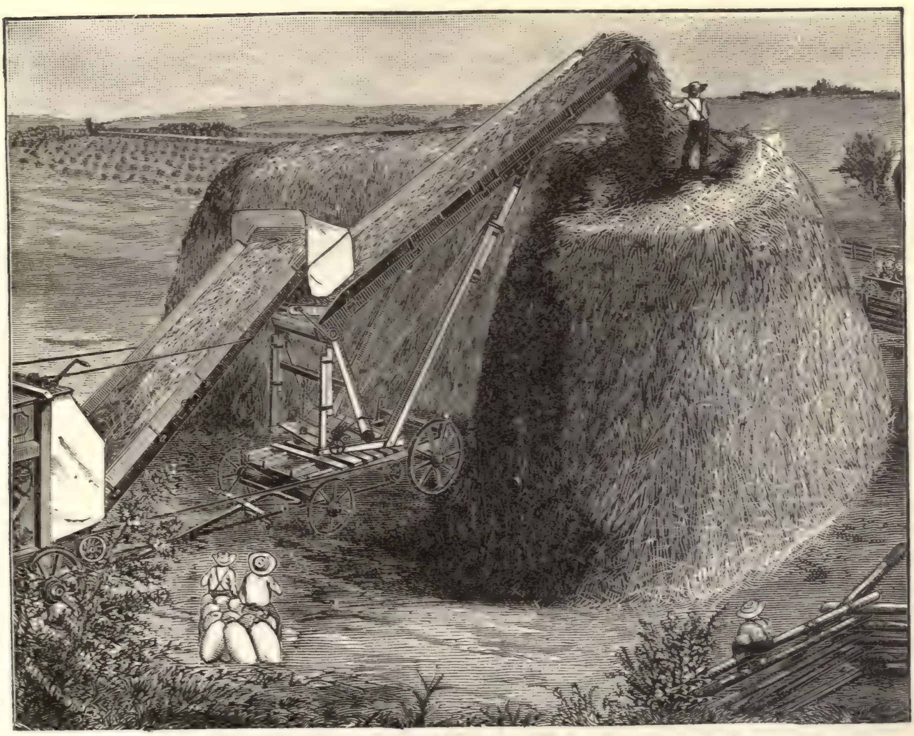


Fig. 6.—Stacker at work.

ous. This attachment is provided with a row of belts which intercept the sheaves of grain delivered by a man with a pitchfork haphazard into the receiver, down the shake-table of which they are propelled by raking teeth fixed to its surface. This surface has a reciprocating movement longitudinally. A row of spring-teeth is adjustably suspended above

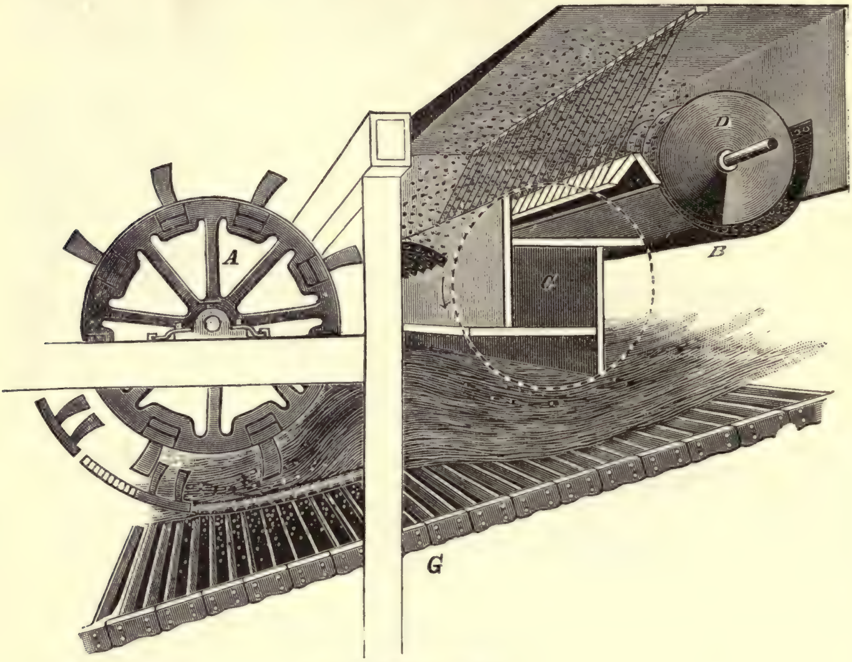


Fig. 7.—Pitt's thresher.

the descending stream of grain, to retard its upper stratum whenever it runs thicker than a determined gauge, while the shake-table uninterruptedly propels the lower stratum at a constant rate of speed into the thresher. A gang of half-moon vibrating knives cut the bands of the sheaves from above. It is made at Racine, Wis.

Trusser, for Threshing Machines.—Fig. 12 is a pair of twine-binding machines, of the

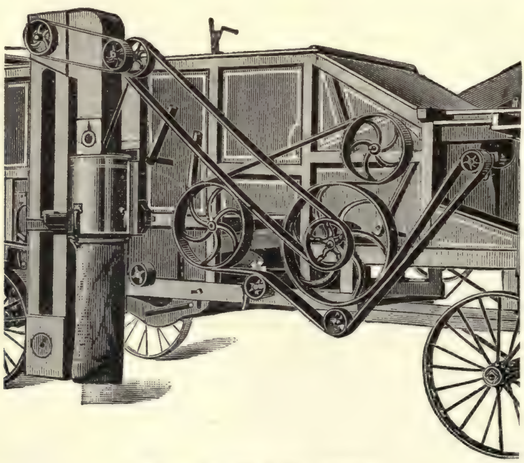


Fig. 8.—Thresher and bagger.

Appleby type, driven by one knotter shaft and one needle shaft for both, by a chain belt from the neighboring shaker spindle of a thresher. When the thresher presents sufficient threshed straw to fill the binder receptacles and trip either knotter, both are tripped in unison by its pressure on the trip lever ; the needles rise and compress the straw into a long

truss, to be bound in two places by the two knotters, and ejected. The attachment is mounted on an independent transport axle, with two wheels and thills for a horse. The

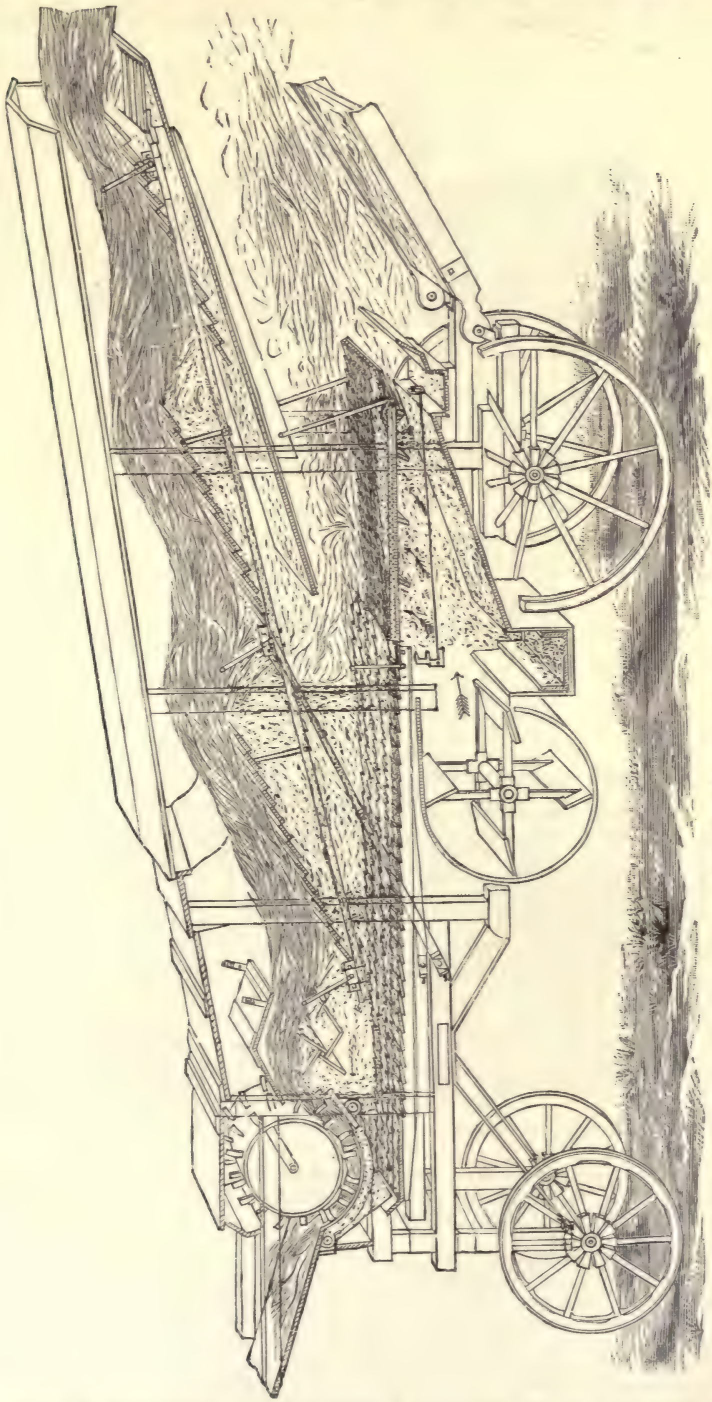


FIG. 9.—Huber thresher. Interior details.

threshed straw on leaving the shakers is forced between two canvas conveyors against the trip levers of the attachment until enough straw accumulates to overcome the resistance of these levers, and thus start the binding mechanism, which automatically stops again after

ejecting each truss, ready for the next presentation of straw. In binding trusses of about 20 lbs. weight, the consumption of twine will be about 600 ft. to the ton of straw. The trusser can be applied to threshers of all patterns.

The "Cyclone" or Pneumatic stacker for threshers consists of revolving fans driven

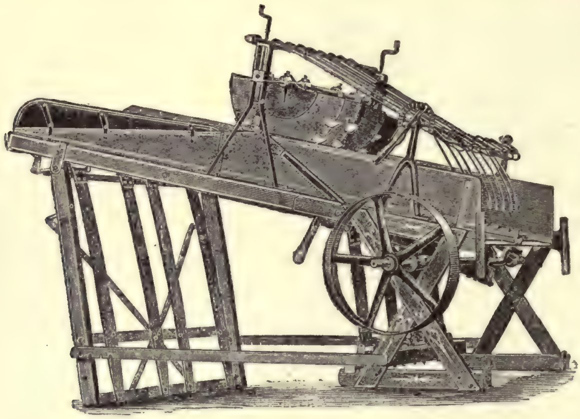


FIG. 10.—Automatic feeder for thresher.

from the thresher, and directing an air-blast into a receiving cylinder, from which straw and chaff pass through a pneumatic spout out upon the stack at any desired height as the

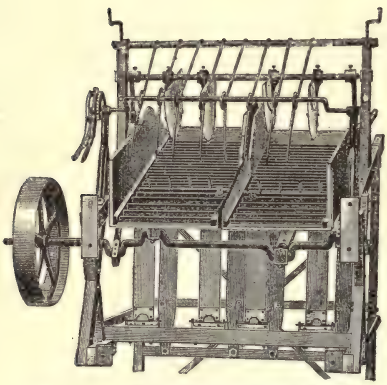


FIG. 11.—Automatic feeder for thresher.

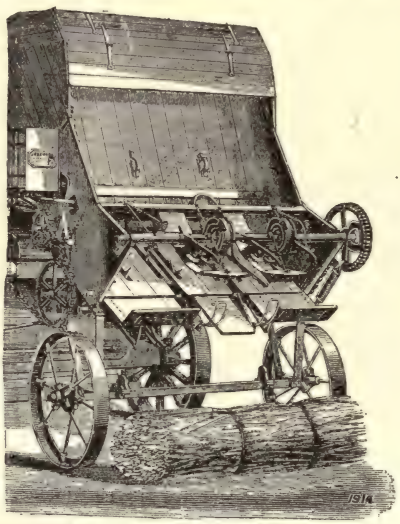


FIG. 12.—Trusser or binder.

growth of the stack progresses. The spout is swung automatically sidewise through an arc to form a long stack. The weight of this stacker complete is about 400 lbs.

Throating Machine : see Wheel-making Machines.

Ties : see Rails.

Tile Machines : see Brick Machines.

Tires : see Carriages and Wagons, and Rolls, Metal-working.

TORPEDOES. An examination of the details of vessels designed, built, and building in all the countries making any attempt to progress in this art, discloses the application of torpedoes to vessels of all classes and dimensions, from the smallest second-class torpedo-boat to the monstrous armored battle-ship. In addition to the boats being built by firms making that a specialty, naval constructors are giving particular attention to a ship of average dimensions to meet the requirements of torpedo warfare. The development has already carried us from second-class torpedo-boats, up through boats of the first class, Fig. 1, torpedo dispatch vessels, torpedo gunboats, to torpedo cruisers and torpedo depot ships.

For all naval warfare there is needed a torpedo possessing high speed, good range, as-

sured directive power, simplicity, and handiness ; it must have inherent and positive directive force to resist any efforts to cause deviation. In order to be launched without deflection from

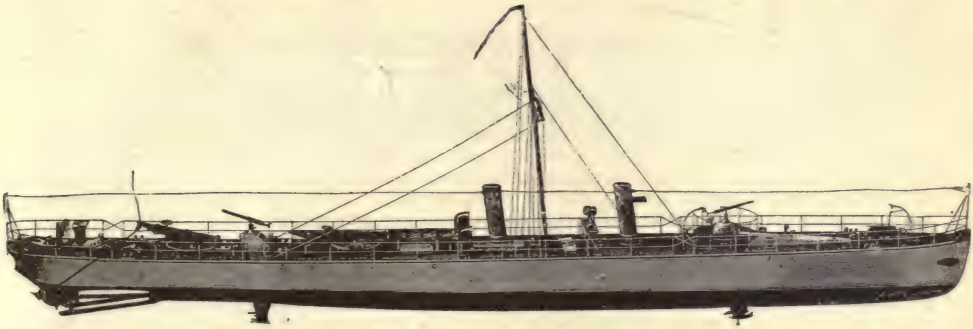


Fig. 1.—Torpedo cruiser.

a vessel running at high speed, Fig. 2, it must possess this paramount quality of maintaining the direction in which it is pointed. Such a torpedo will also be the most efficient for use in defending or taking the place of fixed mines, and for other harbor defenses ; for automatic torpedoes, fired from bomb-proof casemates and torpedo boats, will certainly be relied upon as most important harbor defenses.

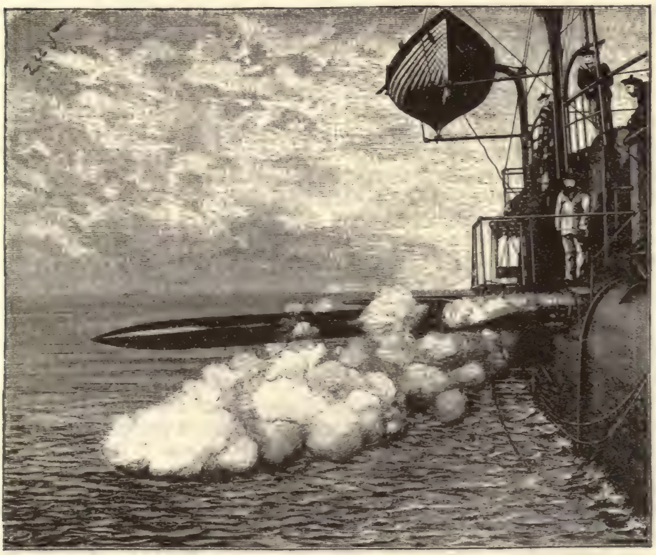


Fig. 2.—Torpedo launched from moving vessel.

As a torpedo is an engine or machine invented for the purpose of destroying ships by blowing them up, and as it is a projectile which may be projected either in the air, upon the surface of the water, or under it, for convenient reference the following subdivisions are made :

I.—Air torpedoes (although a small part of their trajectory may be subaqueous), including rockets and dynamite shell.
II.—Ground and buoyant mines.
III.—Spar, towing, and submarine shells.
IV.—Controllable.
V.—Automatic, automobile, or fish.

Types I., II. and IV. will probably be found useful for discharge from fixed defenses. Type I. are now passing through a series of tests which should determine their usefulness. Type II. are for harbors, channels, and rivers. There may be some isolated cases where circumstances may afford a chance to use Type III. Great development has gone on with controllable torpedoes, Type IV., but none of them have equalled the possibilities of the self-contained fish-torpedo, which will more efficiently supplement the ground and buoyant mines for fixed defenses than any other.

I. Air Torpedoes.—*Rockets* have been familiar for many years, and, although still furnished for signaling purposes, they have not undergone any great development as aërial or aqueous torpedoes during the past decade. Those that were tried in the water have been very difficult to control, particularly if there was a rough sea, which deflected them from their course to such an extent, that they have been known to jump up in the air, and upon again striking the water, to take a course just opposite that in which they originally started. Those intended to pass through the air have been too much influenced by wind and other conditions to admit of any degree of accuracy.

Dynamite Projectiles.—There are two types of projectiles thrown by the dynamite gun now in use, in various sizes, known as full-calibers and sub-calibers. The full-caliber, which fills the bore of the gun completely, consists of a light, strong case containing the explosive, fuse, etc., with a small tube in the rear supporting the rotating blades or vanes which control the direction of the flight. The case or body consists of a steel or iron tube $\frac{1}{8}$ to $\frac{3}{16}$ in. thick, closed at the front end by a brass conoidal-shaped head, and at the rear by a hemispherical base casting of bronze. The base casting has a socket in the center to attach a small tube that supports the rotating blades. Eight blocks of vulcanized fiber, on each end of the shell, center it in the bore, causing thereby friction, heat, vibration, etc.

Shells for a 15-in. gun are usually about 10 ft. long over all, the body being about 7 ft. and the rear extension 3 ft. These have a total weight, when filled, of 1,000 lbs., and contain 500 lbs. of explosive. The fuse is placed either in the point or base, according to its design. The sub-caliber projectiles are smaller in diameter than the bore of the gun, and have no rear extension carrying rotating blades. The blades are attached directly to the body, near the rear end. They occupy a portion of the space between the body of the shell and the bore of the gun, at the same time serving to center the rear end of the shell in the bore. The front end is centered by four wooden blocks which drop off as soon as the shell leaves the muzzle. They are held in place by pins entering into the shell. A wooden disk or gas check is placed in rear of the projectile, filling the bore completely, and preventing any escape of air.

The body of the projectile is made up similarly to the full-caliber, except that the charge only fills about three-fourths of it, the remaining space at the rear being left empty. This is done to keep the center of gravity forward of the center of figure, and so maintain steadiness of flight. Sub-caliber shells 6 in. in diameter, and about 6 ft. long, weighing, filled, 150 lbs., contain a charge of 50 lbs.; those 8 in. in diameter, 6 ft. 5 in. long, weighing, filled, 300 lbs., contain a charge of 100 lbs.; and those 10 in. in diameter, 7 ft. 8 in. long, weighing, filled, 500 lbs., contain a charge of 200 lbs.

Fuses of various kinds have been used the most noted being Captain Zalinski's electrical fuse. It consists of two fuses, one to act instantaneously upon striking a solid target, such as the hull of a ship; the other to act upon entering the water, either instantly or after some seconds of delay. The first may be called an impact fuse, and the second an immersion fuse. The former consists of a battery containing liquid, ready for action, connected through a "low tension" primer. Upon striking the target, the circuit is closed and the primer exploded. This explodes the detonating charge of dry gun-cotton or dynamite, and that in turn explodes the whole charge. In case the shell misses the target and enters the water, the immersion fuse acts. This is similar to the other except that the battery contains no exciting liquid—is perfectly dry. As the shell enters the salt water, the battery becomes wet and active, which immediately causes explosion, unless a delay is desired, in which case a powder train is used. Mechanical fuses have been sometimes used. These generally act by impact either against a solid target or the water. An ingenious fuse of this class was designed by Mr. H. P. Merriam. One of its most peculiar features is a small wind-mill at the point of the shell, which unlocks the firing hammer as the shell passes through the air. It has two sets of caps, one intended to act when the shell strikes a solid target, the other when it strikes the water. The water enters an opening in the point and presses a plunger backward, driving the caps against the hammer, which in this case is a steel ball. When a solid target is struck, the point of the shell is crushed in, thus firing a set of caps arranged inside. Delay action can be given by a powder train.

The projectiles are not designed for penetration, but at Shoeburyness in England, a 10-in. sub-caliber, weighing 500 lbs., was fired into a butt of sand, situated 600 yds. from the gun, and it penetrated 47 ft. The accuracy of fire is very remarkable, even when compared with modern rifles. The following table is a record of the ranges and deviations obtained at Shoeburyness during experiments by the English Government.

8-*in. Sub-calibers. Initial Pressure*, 1,000 *lbs. Wind*, 8 *ft. per second.*

Number of round.	Elevation.	Range.	Deviation from line of fire.
1	20°	3,647 yards.	17·2 yards left.
2	"	3,643 "	20·8 "
3	"	3,647 "	18·6 "
4	"	3,640 "	22·6 "
5	"	3,644 "	21·2 "

See GUN, DYNAMITE.

II. SUBMARINE MINES.—Some of the most important improvements in submarine mining are the following: The modern high explosives and smokeless powders have largely superseded gunpowder, making it possible to have much less bulk, while retaining an equal amount of explosive force. It can readily be seen that this is an extremely important consideration, since upon the size of the torpedo depends the depressing effect of the current; hence the amount of buoyancy necessary to keep the case always high enough to be touched by an enemy's vessels in passing. This buoyancy regulates the weight of anchors and mooring connections that hold the buoys in place, and in fact the principal dimensions of the system.

The increase in intensity of explosive action is also of importance. A long series of tests have been conducted to determine the effective range of different charges of various explosives,

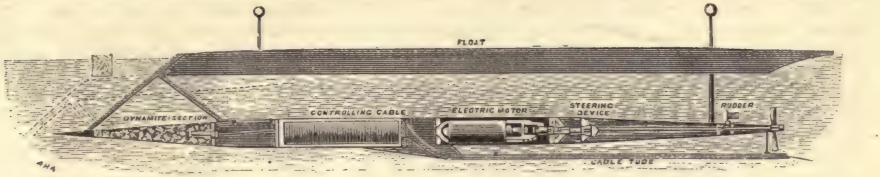


FIG. 3.—The Sims-Edison torpedo.

sunk at varying depths below the surface of the water. By careful measurements of several hundred explosions, the matter has been successfully brought within the scope of mathematical analysis. It is consequently well determined as to the best method of planting these submarine mines, so that, while having their maximum effect on the enemy, their action on each other will be at a minimum. Plans of mining fields for the protection of all of the principal harbors are now well-recognized features of a general system of defense.

III. SPAR TORPEDOES have undergone but little change in recent years, the substitution of a hollow iron spar for wood, and the changes made necessary by the adoption of gun cotton for gunpowder, being the most important.

IV. CONTROLLABLE TORPEDOES are those which, by wire or other connection, are constantly under the direction of the operator, and are found to be most effective when operated from the shore against ships in narrow channels. The location of those requiring a fixed plant will be known and their attack visible or anticipated.

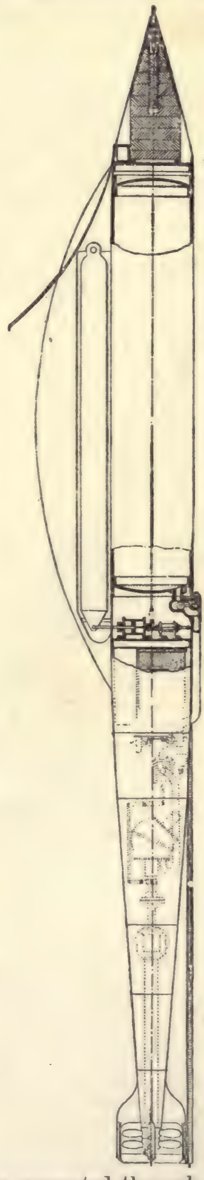


FIG. 4.—Victoria torpedo.

The Brennan Torpedo has been adopted by Great Britain as an auxiliary weapon for harbor defense. It is said to have attained a speed of 20 knots; its weight fully equipped is 25 cwt., and it can be regulated to run on the surface or submerged; it can be steered 30° to 40° to port or starboard, but cannot be maneuvered back to its starting point. It is launched down ways, and further propelled by the unwinding of wire from reels in the torpedo. The wire is drawn in and wound up by two drums driven at a high speed by a stationary engine on shore, close to the ways. The unwinding wire turns two reels in the torpedo on concentric shafts. The immersion is regulated by two horizontal bow rudders, worked automatically by a pendulum and hydrostatic piston.

The Patrick Torpedo is about 24 in. in greatest diameter and 40 ft. long. There is a float attached to the torpedo 46 ft. in length, so placed as to overlap the rear of the torpedo 6 ft.; its greatest diameter is 18 in. The torpedo is submerged about 3 ft. below the surface. The weight complete is about 7,500 lbs., the explosive charge being 200 lbs. The result of four runs showed an average speed over a measured mile of 20·21 statute miles. For this torpedo are claimed good speed, great regularity during entire run, and considerable mobility. An elaborate and special fixed plant is not necessary, the motive power being carbonic acid carried in the torpedo.

The Nordenfeldt Torpedo is cigar-shaped, like the majority of its class, and it moves 6 ft. below the surface, two floats indicating its position to the manipulator. The motive power, the propelling and steering apparatus, and the cable, are all in the torpedo. The electric motive power is supplied by 120 storage cells, the steering being done by a balanced rudder manipulated from the shore.

The Sims-Edison Torpedo, Fig. 3, has two parts, the float and the fish, connected by means of steel bars. The former is filled with stuff having cotton as its chief component, while the latter, 6 ft. under water, contains the explosive matter, cable, electric motor, steering device, rudder, propelling screw and cable tube. There are four compartments; in the forward is the explosive; the second is the buoyant chamber; the third holds the cable, not on a reel, but ingeniously wound into a hollow coil; while the fourth has the electric motor and steering gear. There is a series of magnets for steering and handling the engine, all of which are connected through the cable to the operator at the pole-changing key and switch on shore. This torpedo has been

largely experimented with in this country, and is now being made in France as well as in the United States.

The Victoria Torpedo, Fig. 4, is designed for both coast defense and ships' use. The forward compartment contains the explosive charge in its lower part, and Holme's light composition in the upper. The depth, when running, is controlled by a horizontal rudder. actuated by a pendulum and servo-motor. In rear of this is the electrical cable chamber, containing 1,200 yards of cable. Vertical steering rudders are controlled by a motor in the rear part of the torpedo. An arrangement is also made by which the torpedo can be launched from fixed under-water positions well clear of the shore, a buoy containing cable being sent with the torpedo. To operate the torpedo from such a position, it is started off, pulling cable out of the buoy, the starting effected by means of cable connection with the shore.

V. AUTOMOBILE, OR FISH TORPEDOES.—*The Whitehead Automobile Torpedo* consists of a cigar-shaped envelope of steel or phosphor bronze, containing six compartments for its propelling, directing, and exploding mechanism. Its motive power is compressed air; it is propelled by two two-bladed screws, revolving in opposite directions about the same axis, in order to neutralize their individual tendencies to produce lateral deviation; and it is maintained at a constant depth by horizontal rudders, and on a straight course by vertical vanes set at an angle predetermined by experiment. The forward compartment contains the explosive cartridge and the firing arrangements. The cartridge is made of disks of wet gun cotton, contained in a metallic case, shaped to fit the chamber, and held in place by a felt buffer. The cartridge primer is made of dry gun cotton, and is inserted in the hole in the center of the disks. The detonating primer contains fulminate of mercury, protected from moisture by gumlac. The firing arrangement is made up of a small propeller, working in a sleeve, in rear of which is the firing pin, held in place by a lead safety-pin. The arrangement is such that when the firing gear is taken from the torpedo, the cartridge primer goes with it, rendering the torpedo inoffensive.

The immersion regulators are contained in the "secret chamber," and their office is to control the horizontal rudder after launching, so as to bring the torpedo to a predetermined immersion, and keep it there during its flight. The pressure of water due to depth below the surface acts against a piston, the motions of which are communicated to the horizontal rudders, so that, when the torpedo is below its plane of immersion, the increased pressure will elevate the rudders, and when it is above, the decreased pressure will depress them. When the torpedo is in its plane of immersion the piston is kept in mid-position by an equilibrium between the pressure of the water and the tension of three steel springs. A pendulum works in connection with the above apparatus, so that should the rudders be "hard up," and the torpedo in consequence turn its nose up, the pendulum would swing gradually aft, reducing the rudder angle until the action of the piston has been neutralized, and the rudders are straight.

The impulses of the mechanism in the secret chamber are insufficient to move, unaided, the numerous cranks and rods connecting it with the horizontal rudder. A device called a *servo-motor* is, therefore, interposed, so that the impulses of the regulators are transmitted only to a valve in the machinery chamber, and by the motion of this valve, augmented impulses are transmitted to the rudder rods by means of compressed air from the reservoir, which latter is made of cast-steel forged on a mandrel. A Brotherhood or Whitehead engine, having three cylinders fixed radially upon the shaft, works the propelling machinery. The compressed air is admitted behind the pistons, and evacuated in proper order by three slide valves. The buoyancy chamber is an air-tight compartment, the use of which is to give a certain preponderance of buoyancy to the torpedo during its flight, to insure its returning to the surface, or, by flooding the chamber, to cause it to sink. The bevel-gear chamber comes next, and contains the gearing for making the propellers revolve in opposite directions. Next comes the tail of the torpedo, consisting of the rudder support and the rudders, both vertical and horizontal.

The launching apparatus consists of a torpedo tube, closed at its outer end by a sluice door, and either permanently set into the ship's side, or fitted with a ball-and-socket joint for lateral train, or on trucks for transporting. This tube encases a sliding bronze shield, which, by means of compressed air, can be made to slide in and out on rollers. A hinged door at the breech of the tube is opened, and the torpedo pushed forward into the shield until it brings up against a stopper; a strut, pushed in after the torpedo, prevents any motion to the rear. When the torpedo is set free, the shield doors are all open, and the inrushing water, exerting an equal lateral pressure, simply presses the torpedo directly sidewise aft, without deflecting it at an angle from the desired course. The 18-in. Whiteheads have a speed of from 32 to 33 knots for 437 yards, and 30 knots for 875 yards.

The Howell Torpedo.—The general profile of the Howell torpedo, Fig. 5, is that of a spindle of revolution, the after body being a true spindle, the middle body a cylinder, and the fore body an approach to an ogive. There are four detachable sections. The first (*a*) is the nose, carrying the firing pin and its mechanism. The latter is permanently fixed in a hollow bronze casting, attached to the front end by a bayonet catch for ready handling. The outer end of the firing pin is provided with fan-shaped corrugated horns, to prevent glancing or sliding along the object struck. The condition of the firing pin is at all times plainly visible, its length beyond the nose showing whether it is cocked or not. The dummy and the fighting heads are both made of sheet brass, the former being the lighter, so as to give about 13 lbs. buoyancy. In the fighting head the main part is filled with wet gun cotton (*b*),

a small water-tight chamber being reserved for the dry gun-cotton primer (*c*). Two small holes are drilled through the cap of the primer compartment, and are filled with a substance that is soluble after long contact with water. This is to insure drowning the dry gun-cotton primer, and so preventing accidents.

The main section contains the fly-wheel, with its frame, the propeller gears (*g*), forward sections of shafting, and the thrust bearings. The fly-wheel is gun steel, has a heavy rim and solid web connection with the hub, and is provided with frictionless bearings, no matter what be the plane of the axle when rotating. The connection between the fly-wheel

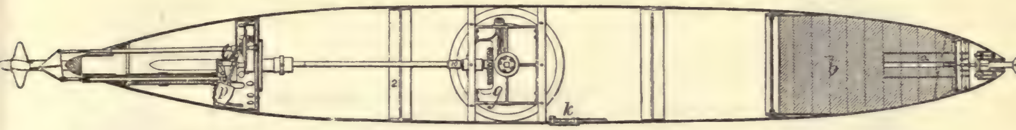


FIG. 5.—Howell torpedo.

and the steam motor that rotates it is made through the starboard side of the torpedo by means of clutch couplings to the end of the axle. The balance of the torpedo is preserved by means of a lead disk (*k*), which is regulated by inserting a key through a hole tapped through the shell. The fly-wheel is geared up to the propeller shafts, which are carried straight to the rear to the right and left-handed screws. The stern section is divided into two compartments, the forward of which contains the diving mechanism, and is open to free access of water ; while the after one is water-tight, and practically empty. The rudder is a steel rectangular plate completely filling the space between the outer ends of the screw-shaft tubes. The steering tillers are directly connected, the one to a hydrostatic piston and the other to a spring. Should the immersion be less than that determined upon, there will be less pressure on the piston, and the spring will hold the rudder partially down and so steer the torpedo down to its proper depth, and *vice versa*.

A pendulum (*p*) has been introduced and suspended so as to swing in a fore-and-aft direction and insure the torpedo remaining in a horizontal position. It is connected with the tiller rod, and by it to the rudder. Two brass air tubes (*H H*) are connected with the main launching tube, Fig. 6, similar to the Whitehead, and connected at their forward ends by a cross tube (*I*). The right-hand tube, called the firing tube, carries a little block (*K K*), in which is fitted a hammer, sear and mainspring. In this tube is placed an ordinary metallic cartridge carrying less than half a pound of powder, sufficient, however, to give the 500-lb. torpedo a discharge speed of over 35 knots. The rear end of the left-hand pipe, called the compression pipe, connects by an elbow with the main tube. The explosion of the cartridge compresses the air in this tube, which, when it enters behind the torpedo, ejects it with sufficient force to keep it from taking the water until it is 30 ft. from the ship. The entire time from pulling the firing lanyard until the torpedo leaves its tube is but little over one second, most of which is taken up by the torpedo itself gathering movement.

The Hall Torpedo has three compartments, the forward containing the magazine and the firing apparatus ; the middle, the air flask and engine ; the after, the diving and righting

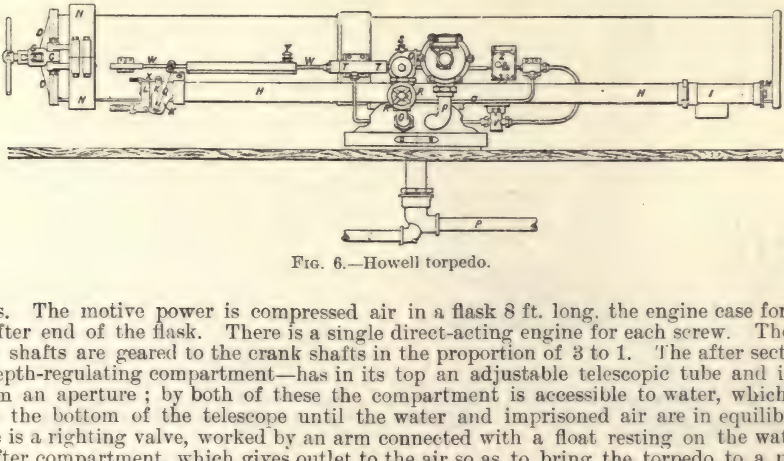


FIG. 6.—Howell torpedo.

valves. The motive power is compressed air in a flask 8 ft. long, the engine case forming the after end of the flask. There is a single direct-acting engine for each screw. The propeller shafts are geared to the crank shafts in the proportion of 3 to 1. The after section—the depth-regulating compartment—has in its top an adjustable telescopic tube and in the bottom an aperture ; by both of these the compartment is accessible to water, which rises above the bottom of the telescope until the water and imprisoned air are in equilibrium. There is a righting valve, worked by an arm connected with a float resting on the water in the after compartment, which gives outlet to the air so as to bring the torpedo to a proper immersion. The magazine is pivoted at its after end, suspended by hangers at its forward end, and centered by springs, permitting lateral movement which actuates pectoral fins. When the torpedo rolls, the lower fin is pressed out and the upper one pulled in, thereby preventing a deflection of the torpedo from its course due to rolling.

TRAPS, STEAM. *The Thoens Balanced Steam Trap*, shown in Fig. 1, consists of a cast-iron casing, enclosing a galvanized-iron float, open at the top. To the bottom of the float is attached a sleeve, with a valve seat, which is fitted around a vertical pipe. The latter is fastened to the base of the trap, and connects with the outlet pipe. This vertical pipe is provided with openings at the upper end to discharge the water from the float. As the condensed water accumulates in the trap, the float rises, and the sleeve closes the openings in the vertical pipe until the water overflows the top of the float, when the weight of the water

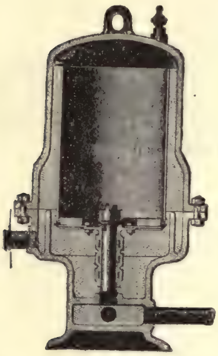


FIG. 1.—Balanced steam trap.

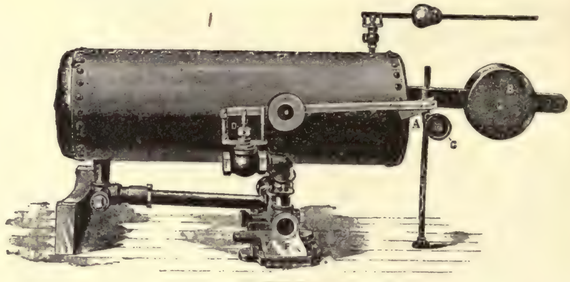


FIG. 2.—The Morehead steam trap.

depresses the float, allowing the water to pass out through the openings in the vertical pipe to the discharge pipe until the float becomes light enough to rise again, when the operation is repeated.

The Morehead Steam Trap, shown in Fig. 2, consists, as shown, of a tank so supported as to be free to tilt upon a bearing between the two check valves, the nearer of which is marked *F*. The open end of the valve, *D*, is connected with the steam dome of the boiler. The water of condensation, returning through the check valve, *F*, enters the tank; and when a sufficient accumulation has taken place to overcome the effect of the weight, *B*, the trap will tilt until the left-hand end is received in the hollow block below. In a socket in the arm carrying the weight, *B*, is secured a standard, upon which is a roller, *C*. When the trap tilts, this roller is brought against the end of the lever of the valve, *D*, raising the valve and admitting steam from the boiler to the interior of the trap. The pressure thus being the same upon the surface of the water as that in the boiler, the water descends by its own gravity, entering the boiler through the check valve opposite *F*. When the trap is emptied, the weight, *B*, returns it again to the position shown in engraving, in which it is supported by the standard, carrying the roller, *C*. The valve lever is attached to a rod, which engages with the base, so that when the trap is in the position shown, the valve connected with that lever will be open, relieving any pressure inside the trap. When, however, the trap tilts again, this valve is seated by the weight upon the lever.

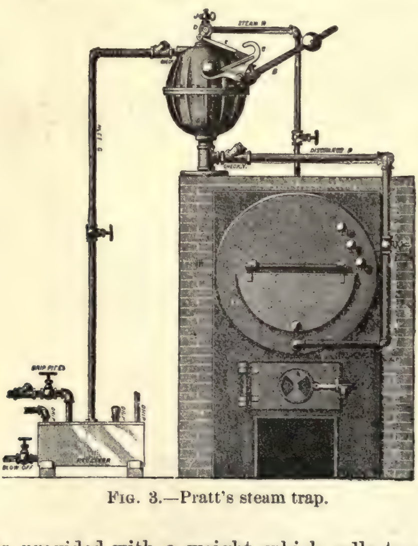


FIG. 3.—Pratt's steam trap.

Pratt's Return Steam Trap, shown in Fig. 3, has a receiving vessel, inside of which is a water-tight cast-iron float, suspended on one end of a lever. The other end of this lever is fast to a spindle passing through a stuffing-box, and carrying on its outer end a lever with a weight, which counterpoises half the weight of the float. A rocking lever is provided with a weight, which rolls to either end, alternately, as the feeder fills and is emptied of water, the rolling ball acting at exactly the same point every time to open and close the steam valve.

Tricycle: see Cycle.
Trimmer: see Book-binding Machines.
Tripod: see Drills, Rock.
Trucks, Fire: see Fire Appliances.
Trusser: see Threshing Machines.

TUBE EXPANDER.—A novel form of this implement is clearly illustrated in the accompanying cut. It is made entirely of steel, except the head, which is of case-hardened wrought-iron. The grooved rollers are journaled in the solid body of the tool. Frictional wear is limited to the rollers and their pin. Each size of tube requires an expander of similar diameter.

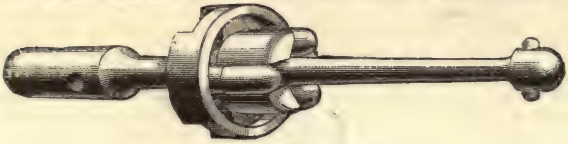


FIG. 1.—Tube expander.

Turbine : see Engines, Steam, Rotary, and Water Wheels.
Twister : see Cotton-spinning Machines.
Twist Machine : see Carving Machines.

TYPESETTING MACHINES. Of the various styles of machines for setting and for distributing type, several have proven of considerable value in the printing of magazines, weekly papers, and books, but until quite recently no apparatus has been found equal to the

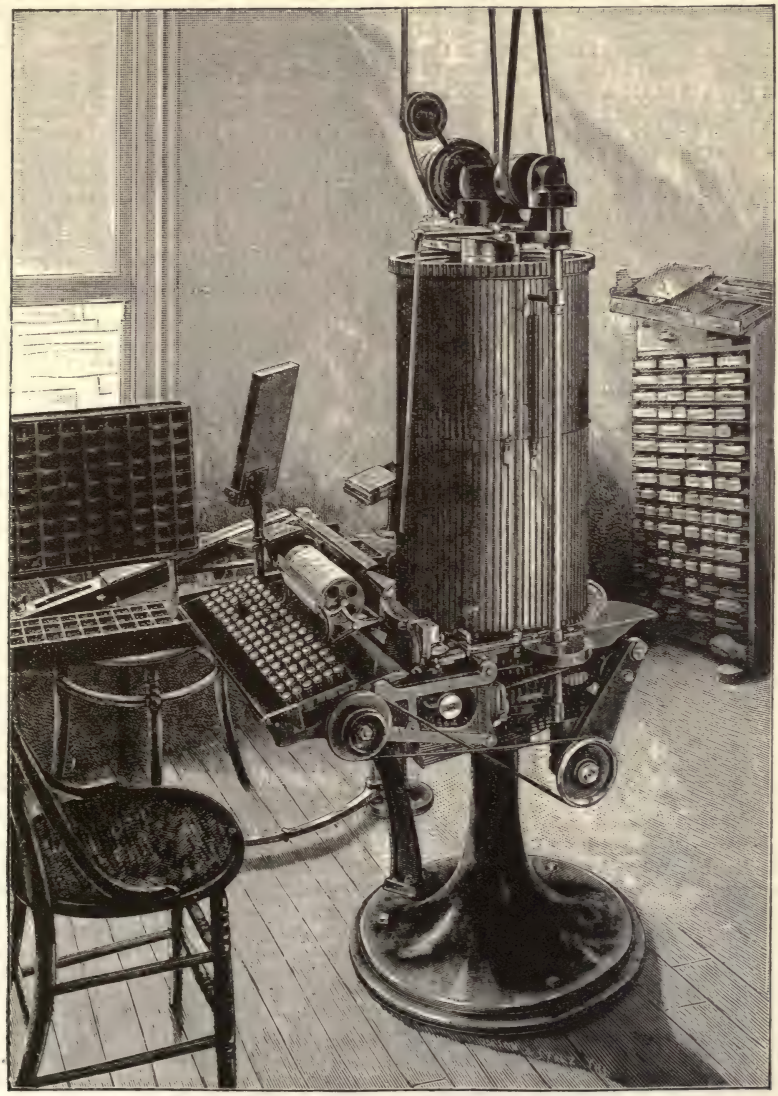


FIG. 1.—Thorne typesetting and distributing machine.

special requirements of large newspaper offices. A machine, combining in one structure the functions of setting and distributing, appears to be the desideratum, and several journals are now successfully using a machine which admirably suits their purpose.

The Thorne Typesetting Machine, of which there are a large number in use, has been lately remodeled and improved, and is now considered to be a practically perfect newspaper machine, combining the features of typesetting and the automatic distribution of the type, after it has been used, back into the machine for repeated use. A general description of the machine, which is shown in the accompanying illustration, is as follows : As will be seen on reference to the general view, Fig. 1, the two principal features of the Thorne typesetting and distributing machine are a keyboard, and two vertical cylinders, having the same axis, the upper cylinder resting upon a collar on the lower one. Both cylinders are cut with a number of vertical grooves, of such form as to receive the type, which is to be first distributed, and then reset. There are ninety of these vertical grooves in each of the cylinders, sufficient to contain all letters, and all kinds of characters that are wanted for ordinary purposes. The keyboard carries a number of keys corresponding to that of the grooves, and when the machine is in operation, whatever key is depressed, the letter corresponding to it is ejected from its proper groove in the lower cylinder upon a circular and revolving table, which has the same axis as the cylinder, but is of larger diameter. Of course, quite a number of types may thus be ejected from the grooves in each revolution of the disk, and all are brought round in their proper order to a point of delivery, where they are conveyed by a traveling band into a guide, and are forced into a parallel position with each other and proper alignment by a striker as they travel in the guide, and they are also gradually turned upward by a twisted portion of the slide ; that is to say, so as to present the face of the letters upward.

The types thus set are discharged in lines into a galley, and by an attendant, provided with a case containing "spaces," are "justified ;" that is to say, the spaces between words are increased equally until the last word, or, if a syllable, with its required hyphen, in each line reaches the end of the line. Proof corrections are, of course, done in the ordinary way.

The control of the types is effected by forming on the side of each character recesses something like the wards of a key, the arrangement, of course, being different for each character. The upper ends of the grooves in the lower cylinder are provided with projections corresponding to these grooves on the types, so that no type will fall into any groove other than that for which it is intended. This arrangement applies only to the lower cylinder, which does not revolve. The grooves in the upper or distributing cylinder are large enough to receive all the types, indifferently, that are fed into them. The work of distribution is effected as follows : A suitable attachment to the side of the upper cylinder enables the operator to place the galley containing the type to be distributed in contact with the cylinder, and by a very simple device, line after line of type is fed into the cylinder until, if desired, every groove is nearly filled, and the upper cylinder is caused to revolve upon the lower one, with which it is in contact. As the columns of mixed type pass over the heads of the differently shaped grooves of the lower cylinder, letter by letter falls into its proper groove as soon as the nicks in the types find their corresponding wards.

This machine, it will be seen, requires accuracy in construction, as do also the types that are used with it, and this has been reduced to an exact system. The types prepared by casting in the usual manner, are set in line, clamped in a slide, and the lines of notches or grooves upon the edges are plowed or planed in them ; the accuracy of the tools employed in these operations determines the accuracy and perfect working of the machine. The grooves have been cast in the characters in several cases. By the use of this machine, types made in the highest perfection of type founding are used, which is not the case in the type of stereotyping or line casting, because the differences in the form or character of different parts of the same font of letters demand for the best perfection differences of temperature and of metal, which are regulated by the skill and care of the workmen in making the type.

In handling the type by this machine, contact of the face of the letter with any of the parts of the machine is avoided, so that the best possible typography is secured by it. The only apparatus or adjunct requisite for this machine is steam power, or other propelling power. As compared with other machines requiring the melting and cooling of metals, and electric batteries for checking errors arising from the derangement of the machine, and air currents for imparting motion to matrices, or other equivalent parts, it is said to be simpler and superior. The use of these machines involves the expense of the wages of these operatives, to-wit : One compositor, one justifier, and one boy for distribution, per machine, and one man to set the head lines for a number of machines.

The Lanston Type Machine belongs to a new class in the typographical art. It is, in fact, "a machine that reads copy, and automatically rewrites it in type metal." By means of the devices invented by Mr. Tolbert Lanston, the functions of the type caster and the compositor are combined in a single mechanical process, the type metal being transferred from the crucible to the galley in the form of composed type, ready for the press. The only manual part of the work is the manipulation of a keyboard, operated independently as to time and place from the type machine proper, the movements of the latter being entirely automatic. This keyboard contains a separate key for every character and space type contained in a complete font. They are 225 in number in the machine now in use, and these are arranged in a bank of 15 rows, of 15 keys each. The depression of any key punches a round hole in a paper ribbon. When the last syllable which can be put in any line has been recorded by these holes in the paper ribbon, the extent to which the spaces of that line must be varied (by being made either smaller or larger) to justify the line, is indicated by a scale, and a record of the degree of variance is made by means of holes punched in singly in the paper. The roll of paper ribbon having been filled with such holes punched at definite close intervals along its length, is next transferred to the type machine proper. It is evident that

as the paper ribbon is placed in the type machine just as it comes from the keyboard. the holes enter the type machine in the inverse order to that in which they were made. and, consequently, the justifying holes will enter the machine immediately before the line to which they apply, and by their presence devices are first put in operation which, while permitting the character types to be formed of proper normal width, automatically alter the width of the space types in the line in the amount previously read on the scale at the keyboard as being necessary to secure the justification of that particular line. The automatic continuance of these processes results in casting the types composing the line in the inverse order of their arrangement therein, and in their being placed in the galley accurately justified, ready to be arranged in the form on the imposing stone.

As a general conclusion, it can be said that these inventions automatically make and set type at a rate daily which will supplant the labor, in its present form, of the type caster, of those engaged in the hand finishing of type at the foundries, and of 5 compositors, a total of 8 persons. To do this requires the services, on an average, of $1\frac{1}{3}$ persons to each type machine and keyboard.

The perfected Lanston keyboard is operated by electricity, and has the power to repeat the same letter or space continuously, so long as any one key is held down, at a rate very much more rapid than can be with comfort accomplished by repeated strokes of the same key. This faculty of automatic repetition enables all "fat" matter to be filled in with surprising rapidity. Thus, if a line is to be cast blank. the key of the "em" quad is held down, and the index races to the end of the line without any effort on the part of the operator. In comparing the work of the keyboard operator with that of the typewriter, the latter has no equivalent to this mechanical repetition in such work as dashes, thus, – – – – –, which requires a separate key movement at each one.

The Rogers Typograph.—In this machine the matrix bars are hung suspended on wires attached to a tilting frame, and are released one at a time by touching a key on the keyboard, or bank, somewhat similar to a typewriter keyboard. These matrix bars, when thus unlatched, travel forward by gravity on their respective wires, and are assembled in a channel, and when the line is complete, the operator puts his foot upon a treadle, and by depressing it the machine automatically justifies, aligns, compresses, and casts the line, and releases and deposits the formed type bar in a galley. These operations, in a foot-power machine, require about five seconds; in the steam-power machine, requiring one-eighth of a horse-power, the operation takes but three seconds, during which time the operator is getting his line, so that the work of the machine is practically continuous.

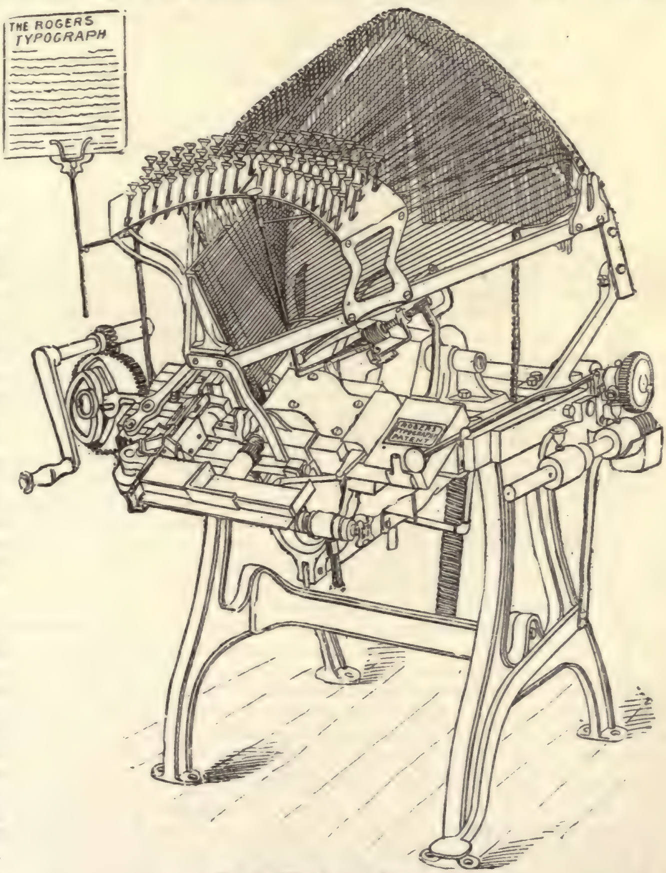


FIG. 2.—The Rogers typograph.

The justification is accomplished by the rotation of a rocking composite-disk of circular form, which at the initial point is thinner than a three-em space. By the use of an off-set in the type bar itself, the justification is done at the point of contact by the justifiers with the mold. By the sole use of the justifiers the spacing is made absolutely uniform, but by employing three-em spaces between short words, un-uniform spacing may be had. Before commencing work, the frame carrying

the various wires and matrix bars is swung down into position, with its front leg resting on a base formed on the center shaft, as seen in Fig. 2, and the compressing arm is swung to the left of the path of movement of the matrix bars ; the latter, by the key action mentioned, form the line of composition in front of the mold, the latches retaining the matrix bars having their appropriate lips inserted between any two matrix bars by reason of inclines on the latter, so as to cause the release from the latches of only the proper matrix bars. When the desired line has been thus formed, the operator desists from further key manipulation, and gives the treadle its primary stroke.

This operates, first, to bring the compressing arm into position parallel with the line of composition, and to a predetermined point positively fixed for the length of the line when it is finally justified ; second, to rotate and move longitudinally a space shaft, which causes disk sections of the compound spaces to move together to cause the spaces to expand the line of composition to the full extent as limited by the set position of the compressing arm ; third, to move the mold slide toward the line of justified composition, said mold slide carrying the aligning plate, which engages with the matrix bars to place their matrices in line, and the slide also operates a space supporter so that the latter may provide rear bearing for the spaces as they are pressed at their forward edges by the mold ; fourth, to swing the melting pot forward and upward so that its discharge conduit will register tightly against the casting chamber ; fifth, to actuate the pump plunger in discharging the molten type metal into the casting chamber.

The production of each cast type bar is caused by one complete revolution of the main driving shaft, subdivided into two semi-revolutions in the same direction, respectively a primary and secondary movement, so that each said complete revolution of the main shaft is the result of two full-stroke movements of the treadle. After a brief duration, sufficient to ensure the cooling and proper setting of the cast type bar, the treadle is given its secondary movement. This rotates the driving shaft the final half of its revolution, which acts to, first, withdraw the plunger of the pump ; second, to withdraw the melting-pot discharge conduit from the casting chamber ; third, to move the mold slide toward the left of the machine, thereby releasing the line of composition from pressure of the mold, releasing the spaces from the pressure of the space supporter, swinging up the upper mold section, and actuating the mechanism which ejects the type bar from the casting chamber ; fourth, to rotate the space shaft in reverse to its previous movement, and place the connecting mechanism in suitable position for a repetition of the operation described under the first treadle movement ; fifth, to move the compressor shaft rearwardly, and throw its arm out of the path of movement of the matrix bars in reverse to its first described movement.

The matrix carrier can then be swung backwardly, so as to distribute the matrix bars which were previously in the line of composition ; each travels back to its own place by gravity, and the spaces which were in the same line may be moved by the space distributor rearwardly, and off from the space shaft, on to a space way, and upwardly on the latter until they are locked by a special latch. The cast type bar, which constitutes the product of the above-described operation, is then ready for trimming, which is done by mechanism operated automatically by means of connections with the treadles and main driving shaft.

The length of line and body of the type bar may be altered very quickly, and the machine may be converted from a minion to a nonpareil, or to any other face for which extra sets of matrices and extra casting boxes may be supplied. An eight-page section of the New York Sunday *World* was, with the exception of the displayed advertisements and heads, set up on a Rogers typograph. The composition was done entirely on one machine, by three operators, working in turn, 8 hours at a time, in 4 days, 23 hours, and 35 minutes, in which time the proof was read, corrections were made, the heads set, and the type placed in chases and made ready for stereotyping, by the same operators, at a total cost of $67.22, the operators being paid at the rate of $27 a week, the regular rate for time work on morning newspapers set by the "piece" in this city. This work, had it been done by hand, it is estimated, would have cost, including time, making ready, and proof reading, $173.01. A speed of over 7,000 ems an hour has been attained in setting memorized matter on a sixteen-em pica line, minion machine, and this seems likely to be excelled.

The Linotype (*Mergenthaler's patent*) is a machine now extensively used, and which enables an operator working at a keyboard attached to the machine to set lines of type of any required length ; such lines, upon completion and perfect justification mechanically, are then cast as solid lines, and dropped into a galley while the succeeding line is being set and justified. The linotype has a keyboard of 107 separate keys, arranged in six rows, and this number of keys is said to be sufficient to cover not only all required faces of type to be used as from one font, but also, on some machines, to meet the requirements of many logotypes with faces set bodyways, such logotypes being much used in printing addresses for wrappers, thus : Mrs. John Jones : the twelve months, expressed by three letters each, Jan , Feb., Mar., etc. ; Mr., Mrs., Dr., Prof., etc., to the extent perhaps of 20 additional keys. The fundamental parts of the machine are a series of female type or matrices, each containing a single letter or character, and a series of spacing devices or guides, each of which is capable of movement to variable thickness. The assorted matrices are arranged in the channels of a magazine, provided with escapement devices connected with finger keys, so that the operation of a key is followed by the discharge of a matrix bearing the same character. The space bars are arranged in a magazine, and discharged in like manner.

As the matrices emerge from the magazine, they are received on an inclined traveling belt, by which they are delivered one after another into a receiver, in which they are composed or assembled in line together with the spaces. The composition continues until all the characters to appear in a line are assembled. The operator then depresses a lever, and the assembled line of matrices and spaces is transferred to the face of a mold having the internal dimensions of the required linotype. The matrices and spaces thus assembled act jointly to close the face of the mold, and while in this position the spaces are automatically adjusted to elongate the line to the required limit, or, as technically termed by the printer, to "justify the line." A melting pot, containing at all times a supply of molten type metal, and provided with a force pump, is connected with the mold, and after the line of matrices is presented to the font, the pump causes the molten metal to flow into and fill the mold, where it

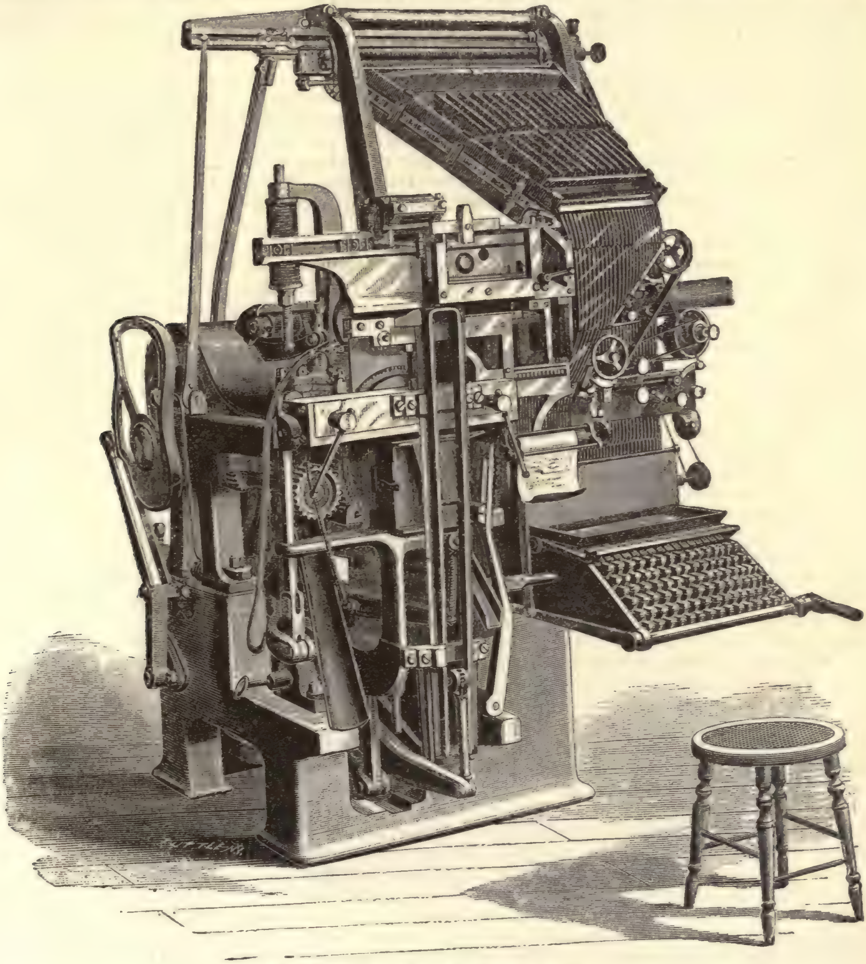


Fig. 3.—Mergenthaler linotype machine.

solidifies in the form of a bar or "linotype," bearing on its edge the impress of the matrices which are, for the time being, assembled in the front. After the linotype is thus formed, the matrices are withdrawn, the mold moved, and the linotype automatically ejected and added to the series which preceded it. As soon as the line of matrices and space bars is removed from the mold, the spaces are separated and returned to their magazines, while the matrices are transferred to a distributing mechanism, by which they are returned to the magazine channels from which they started.

The distributing mechanism is of extreme simplicity. It consists, essentially, of a single bar extending horizontally above the upper ends of the magazine channels, and having along its sides a series of horizontal ribs, which differ in number and arrangement, over the respective channels. The matrices have their upper ends notched and provided with teeth, by which they may be suspended from this bar while being moved lengthwise thereunder. As each matrix is thus moved along the bar, its teeth may engage and disengage certain of

the ribs, and when the matrix reaches a point directly over its appropriate channel, all of its teeth are, for the first time, disengaged, and it is permitted to descend by gravity into the magazine, there to remain until all of its predecessors in that channel have been called into use.

A simple mechanism is provided for transferring the matrices, one at a time, in rapid succession, to the distributor bar, and for carrying them along the bar to the points of discharge. The organization of the machine is such that the manipulation of the keys to assemble the characters for one line, the casting of the preceding line, and the distribution of a still earlier line, are carried on concurrently and independently. The machine is operated by a small expenditure of power. Its principal parts move slowly, and the task of the operator is limited to the manipulation of the finger-keys and the simple movement required to start the line. As soon as one line is completed and started to the caster, he proceeds to set up another line. The keys are operated with a lighter touch than those of a typewriter. The capacity of this machine, as now speeded, is from 8,000 to 10,000 ems per hour.

Fig. 3 is a perspective of the complete Mergenthaler linotype machine.

The Munson Method of Power Type Composition has been recently simplified and improved, so that features formerly criticised or excepted to by practical printers have been eliminated. It has been considered that most of the typesetting and composing machines heretofore placed before the public were limited in their capacity for work by the ability of the operator, and that, with the average manipulation, from one-half to three-quarters of the capacity of a well-constructed machine remains idle. The object of Mr. Munson's inventions is to overcome this defect in typesetting machinery, and to make it possible to work up to the absolute maximum speed. He uses three machines, viz.: A preparatory perforating machine, a typesetting machine, and a type-distributing machine. The preparatory perforating machine is small and simply constructed. It is provided with a keyboard that can be worked by any typewriter operator at any time or in any place, and the result (a strip of paper having a series of transverse rows of perforations) can afterward be used to operate the typesetting machine. By this plan two, three, or possibly more persons can be employed simultaneously in keeping one typesetting machine constantly at work. This preparatory or "compositor's" machine works as follows: To each letter, point, figure, space, quadrat, etc., is assigned a particular row of perforations in the ribbon, the rows being made to differ from one another by changes in the combinations of their perforations. The operator has only to see that he depresses the proper keys in their right order, the machine itself taking care of the combinations and insuring the correct perforations of the ribbon. The operator determines as he goes along where each column line of type shall end, in substantially the same way that a typewriter operator decides where each line of typewriting shall end. That is, he is guided by an index moving along a graduated scale, and also by the sound of a bell that is struck automatically a little before the end of the line is reached, just as the typewriter operator is guided by the "carriage scale" index and bell of that machine. When the end of a column line is thus fixed upon by the operator (whether the division comes after a word, after a hyphen dividing a word, or after a point, figure, or other character), he marks the terminus of the line by touching a key that causes to be inserted at that point in the ribbon a row of perforations that represents a peculiar type, called the "line divider." He then proceeds in like manner to compose the next line.

The typesetting machine has no keyboard, but is automatic in its action, and is operated entirely by mechanical power, its work being directed by the perforated strip. Automatically it does the following things: (1) It sets matter in a long, continuous line of type, this line consisting of a succession of separated short lines, each of which has the requisite length and the proper terminal division to make it, when spaced and justified, a correct and suitable column line. (2) It spaces evenly, and justifies with exactness each of such column lines, and then deposits it with the column of type on the galley. (3) When matter is required to be leaded, it inserts leads between the lines of type as they are moved on to the galley.

The type used with these machines is the ordinary type made and sold by typefounders. The power type distributor is entirely automatic; that is, it will not require the "dead" matter for distribution to be fed into it by hand, but a whole page or column of type may be placed on its table, and the machine itself will do the rest. It separates the foremost line of type from the others, and then picks off each individual type and places it in its proper reservoir.

The Electric Linotype Machine, based upon the inventions of Mr. Shuckers, and further improved by Mr. Homer Lee, is an automatic type-bar casting machine, differing from the Mergenthaler and Rogers machines in that, instead of using female characters of the matrix order, it employs male or cameo characters secured to the ends of bars arranged in the arc of a circle over a key-assembling channel, the bars being arranged in lines radial to their key channel. Any number of bars with like characters may be used. The bars are released, one at a time, by electro-magnets operated from a keyboard. When released, each bar falls by gravity with its type end in place in the assembling channel in front of the operator, each succeeding bar, as it falls, taking its place alongside of the preceding bar. The automatic justifying spaces are similarly released by a proper key and electro-magnet to fall in place between the type bars, and when the line is completed the machine automatically clamps the types in place, and at the same time moves the justifying spaces simultaneously all to equal distances, so that the line is automatically justified at the time it is clamped rigidly in place. The soft lead bar is then fed beneath the line of clamped type bars, and is moved up into forcible

contact with the type faces by a proper plunger, which causes the soft lead bar to be impressed with a line of characters which thus appear in the bar in female or intaglio form. The plunger then withdraws, the soft lead bar is released and moves forward into position in line with the mouth of a type-bar mold. The molten type metal is then automatically forced into the mold against the face of the matrix, the mold withdraws slightly, and carries the cast type bar around in contact with a rear knife, that trims the under face of the type bar and deposits it in proper order into a galley, to be afterward taken to the composing table. As soon as the plunger withdraws, and the soft metal bar is thus released, other bars may be fed in, one at a time, automatically, so that the matter of the first bar may be duplicated one or more times, as may be necessary. When a new line is to be set up, the operator pulls a candle, and the type bars move back to their normal positions ready for the operator to assemble another series of bars. The automatic justifier referred to is the invention of Mr. Shuckers, and forms a very important part of the machine, and is, in fact, necessary to all automatic linotype machines, and is one of the most ingenious parts of the machine.

TYPEWRITER OR WRITING MACHINES. Typewriting machines may be divided into four general classes, viz.: Type-bar machines, or those having type attached to the ends of bars, so arranged as to strike at a common printing point; wheel machines, or those having type arranged upon segments of a wheel, which are swung into a printing position by modified levers; cylinder machines, or those having type arranged upon cylinders, and so governed by levers and auxiliary levers as to oscillate to a proper printing position; and one-hand machines, so-called, as they are designed to be operated by one hand. There are more type-bar machines in use than all other classes combined.

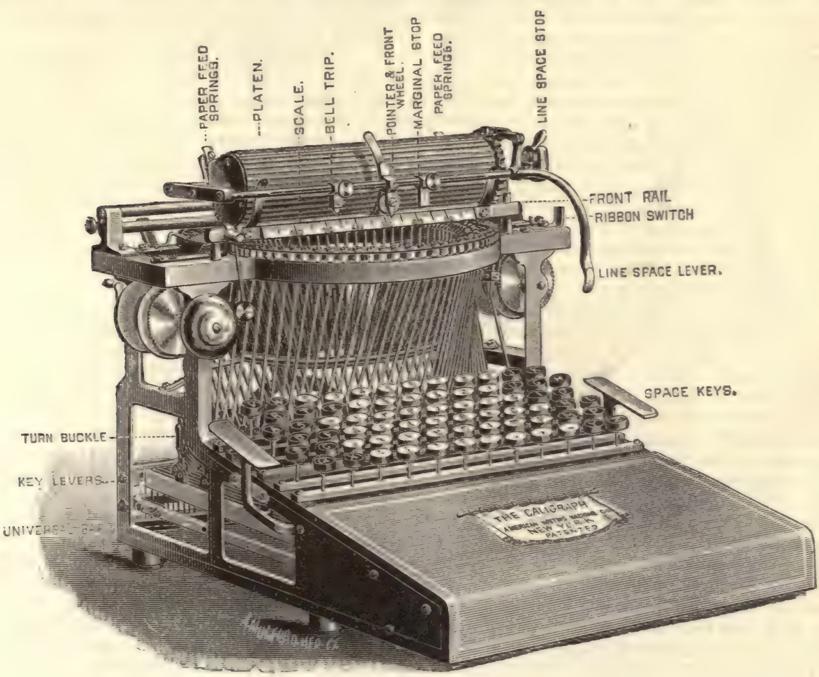


FIG. 1.—Caligraph typewriter.

bined. There are two classes of type-bar machines—those printing with an upward stroke, and those printing with a downward stroke. The Caligraph, Remington, Smith Premier, Yost, Densmore, and National belong to the first class. The Franklin, Bar-lock, and Williams belong to the second.

I. TYPE-BAR MACHINES.—*The Caligraph Typewriter*, Fig. 1, is a type-bar machine, having a common printing point, at which the type strike by an upward motion of the type bar. This point is exactly in the center of the basket, and when any key is touched the type corresponding to it rises with a sharp, quick blow, leaving an imprint at that particular point. By an automatic escapement, the carriage, with its load of paper, is allowed to glide easily onward so that the next character will appear at its proper space distance from the preceding one. This, in a general way, explains the operation of the machine, but a number of mechanisms are set in motion by simply touching the key. The carriage movement and ribbon movement are effected simultaneously. A rectangular rocker bar is pinioned at the rear base of the machine by means of a pair of studs and check nuts. It rises in a perpendicular position, reaching across the top plate at the back. Below, it is connected to a U shaped universal bar, which reaches out under the key levers in such a way that

when they are depressed the same motion is given to it, and in turn carried forward to the rocker bar, which receives a $\frac{1}{4}$-in. vibration at its upper part. In the middle upper part of the rocker bar a dog is pinioned, which engages the teeth of a double rack hung directly over it from the carriage. A driving arm is connected to a strong torsion spring underneath the machine, and then in turn to the forward rack, by means of an ordinary link and stud, so that there is a continual pressure upon the rack and carriage from right to left. The dog engages the rear rack when the machine is at rest. The two racks have an independent action within the limits of one rack tooth. Between the two is a small spiral spring, which, when the machine is at rest, is stretched by the stronger tension of the torsion spring ; thus when the dog engages the teeth of the front rack, the strain is taken from the rack spring, which resumes its normal position, carrying the rear rack with it the distance of one tooth. In this way, the teeth of one rack are always opposite those of the other, and the dog plays back and forth, allowing the carriage to travel easily onward one space at a time. The vibration of the rocker bar gives the forward and back action to the dog, which engages first one rack and then the other.

At each side of the rocker bar is attached a pawl, engaging the teeth of a ribbon ratchet, which works on an eccentric giving a lateral movement to the ribbon. The ratchet is at one end of a short shaft, having at the other a small cog, geared to a larger one. The larger cog is pinioned to another shaft, which, as it turns, reels the ribbon. The shafts are at right angles, and, working together, give the ribbon two movements, thus exposing at the printing point a fresh part of the ribbon for each type impression. Thus a positive ribbon movement is secured, and the whole printing surface of the ribbon is utilized. By means of a switch at the back, the cogs at either side of the machine may be thrown in and out of gear at pleasure. Thus when the ribbon has been wound upon one spool, the switch is reversed and it is reeled upon the other. The lateral motion continues when either is in operation.

The keyboard, which consists of 78 characters, is so arranged that the letters most frequently used are most conveniently placed, and those least often used are in less prominent positions. The small letters occupy an oblong space in the center, about 7 in. long and $2\frac{1}{2}$ in. wide, distributed over three banks. Directly above the small letters, are six characters in common use ; above these are the numerals. Below the small letters are the different punctuation marks, and at the right and left appear capitals, which are white upon a black background. It is designed that the left hand shall operate "*e*," "*f*," "*n*," and those at the left of them, and that the right hand shall operate "*y*," "*g*," "*l*," and those at the right of them. With this as the dividing line, the letters are arranged as far as possible so that in the majority of words the hands will work alternately in producing the letters, which is essential for rapid work. The keys are made from a composition which is easy to the touch, and from its dull luster is not trying to the eyes. Six bridges reach from one side of the frame to the other, through which key-stems pass, serving as a guide to them. Below, the stems are joined to equalized levers, which are made to operate type bars by means of long connecting rods. Hangers radiating from the center of the basket are attached to the top plate, supporting other levers. These are the type bars, which, being struck up from sheet steel, are hollow, thus securing lightness and strength. A conical bearing, which is tightened by an adjusting screw, insures a positive and permanent alignment. The type are set at the extreme end of the bars, affording a leverage of such power that by means of impression paper 40 copies can be made at once. For this reason the Caligraph is used by press associations and telegraph companies in taking matter for publication direct from the wire. By means of it, all the New York dailies are furnished immediately with a clearly-printed copy of important news. The old method of writing out messages as received is gradually being discarded, and even personal telegrams are received in the same manner.

The carriage glides easily forward upon a rod at the back of the machine, supported from the frame by ordinary standards. At the front center, the carriage is supported by a small wheel of hardened steel. A yoke with steel collars connects the carriage to the traveling rack, and thus they move together, one space at a time, and just as fast as the dog passes from one rack to the other. The paper is fed into the machine from behind and passes between two rubber rollers which hold it firmly in place. The smaller of the two, the feed roll, is pressed firmly against the larger by means of feed springs, held in place by set-screws. This insures an even tension at both ends and causes the paper to feed straight. It also admits paper of any thickness and any number of sheets, as the set-screws make the apparatus adjustable. This is one of the most valuable recent improvements. There are two interchangeable rollers or platens, of different diameters, for each machine. These are adjusted, the one for single copy work and the other for manifolding.

The Remington Machine (Fig. 2).—The printing is produced in this machine by type bars rising, so that one set of type strikes at one common printing point, and another set of type strikes at another common printing point, both of which are a trifle off the center of the basket. These bars are hung from the top plate of the machine. The type, however, are arranged in pairs upon the type bars, so that one key answers for two type, requiring, however, an auxiliary shift when any of the upper-case letters are required. This gives a smaller keyboard, there being but 40 keys, which obviously represent 76 characters, as two keys are used for shifting. While this arrangement gives a more compact keyboard, two separate strokes are required to produce any of the upper-case letters. The stroke is made by levers fulcrumed at the back of the machine. This is an easy leverage, requiring a $\frac{5}{8}$-in. stroke. The carriage is a 7 × $9\frac{3}{4}$ in. frame, which rides upon three wheels, two being at the back and one in front. Those at the back are grooved to fit the back rail, while the one in

front is flat and has a plain track. The platen, feed roll, and connecting gear are fitted to slide forward and back when a shift from one case to the other is required. Two yoke blocks connect these to the shift rail, which is in front. This rail has a forward-and-back movement corresponding to that of the carriage. A strong spring holds it well forward, so that the printing surface of the platen remains directly over the lower-case type. To print an upper-case character, the shift key is pressed, throwing the platen back, with the printing surface directly over the upper-case characters. In the Caligraph the platen is corrugated, giving a flat surface upon which the type strike, and the type faces are plain; while in this machine the platen is round and type faces are concave. Two rubber straps, which pass beneath the platen and around each end of the feed roll, hold it in place. By switching, the platen may be made to hold a constant upper-case printing position, and then the lower-case shift must be used to find lower-case characters. This is useful in tabulating work and in printing headings. The carriage is drawn from right to left by a coiled spring attached to it by a leather strap. A yoke with steel bushings joins the carriage to a rack which engages its teeth with a dog in such a manner that the movement is made one space at a time. Here, however, the rack is single and the dog double, being split. When the machine is at rest, the forward dog engages the rack teeth and is pressed forward against its spring until aligned with the rear dog. By a rocker-bar movement both dogs are swung forward at each stroke, and just far enough to free the forward dog, when its spring carries it back the distance of one tooth. As soon as the rocker bar, resuming its normal position, has carried the front dog through the next tooth, it is again sprung forward and the spacing is made.

FIG. 2.—Remington typewriter.

A ratchet is attached to the shaft carrying the coiled spring, and so arranged that it gears only when the carriage travels from right to left. At the other end of this shaft is a cog, which engages the teeth of another cog turning a shaft at right angles to it, which carries the ribbon spool. Thus the ribbon is reeled as the spring gradually unwinds, and receives its power from that spring, thus lightening the touch. The intermediate shaft just mentioned has bearings at both sides of the machine and is geared the same at both ends. By means of a switch, either one can be put in gear, and when the ribbon has been wound about one spool, it can be reversed and wound about the other.

The Smith Premier (Fig. 3).—The impression of the type is made in this machine by the same upward stroke as in those previously described, but the type bars are arranged in a different manner. They are hung on $1\frac{3}{4}$-in. bearings, one half of them being supported above the plate, and the other half below. But instead of forming chords of the plate circle, as in the machines already described, the bearings are secant lines to that circle, and the type bar proper is at the extreme inner bearing. In making a strong, firm stroke, the type bar should be at right angles to its bearing, but from the position of the bearing this is obviously impossible, and so the bars are bent in such shape that the line of the bar at its striking point has such a position relative to its bearing. The theory is that with the increased length of bearing, the alignment will be permanent. The rocker-bar movement is used throughout the machine. Connecting rods are attached to the other end of the type-bar bearing, and thus the ends draw against each other when the bar is in operation. The key levers of this machine are entirely different from what have been described. Circular bars, 76 in number, and about an eighth of an inch in diameter, reach from front to rear and below the keyboard. They have a bearing at each end, and work with a circular movement. A rocker-bar movement attaches the key

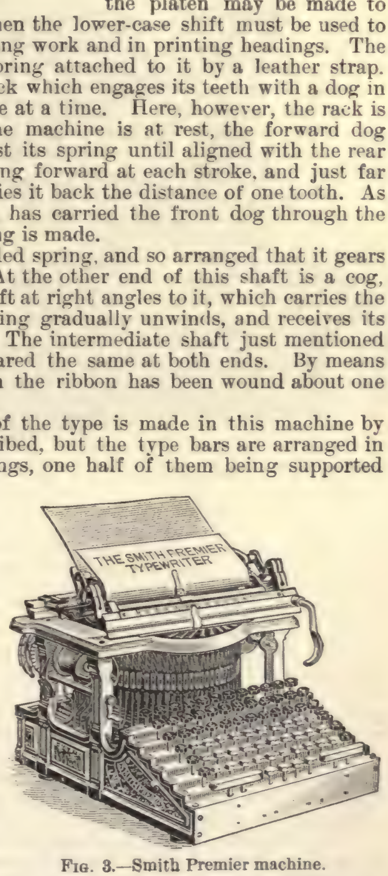


FIG. 3.—Smith Premier machine.

stem to this bar, and the same kind of an arrangement is used for joining it to the connecting rods. These rocker-bar levers are arranged in 12 banks, with those of a bank directly over each other. The keyboard consists of 76 characters, corresponding to the same number of rocker-bar levers and type. Its arrangement is quite different from either keyboard described. The capitals are arranged in three banks above, and the small letters below, where they are conveniently touched. The numerals are arranged at the sides, and the punctuation marks occupy the remaining spaces. The carriage moves upon ball bearings, which have an enclosed track of their own. This arrangement insures a steady, even motion. The platen is hung on an open bearing, and is so attached to another set of bearings above that it can be swung out of its true bearings forward, so as to expose to the operator's view the printing surface of the platen and any writing upon the paper. The feed roll is attached to the rear carriage rod, so as to admit of a swing motion, governed by springs which press it against the platen. By pressing the paper table forward the two are disengaged and the paper can be easily removed. The carriage is attached to a coiled spring at the rear of the machine by a fine steel chain, and is carried from right to left by it. The spring is joined to a wheel which turns upon a shaft, reaching from front to rear as the side. Back of the spring wheel is a weight, hung on an eccentric which rises and drops as the wheel turns,

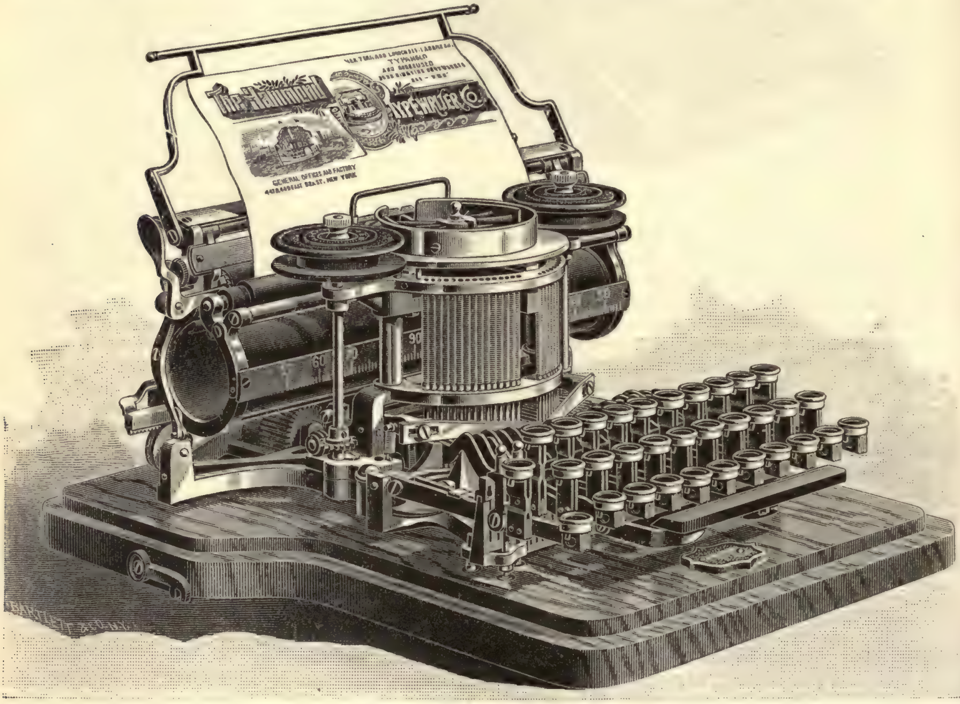


FIG. 4.—Hammond typewriter.

thus striking a bell. It is gauged, as in all machines, to trip and strike at the end of each line of writing. The ribbon spool is hung loosely upon this 6-in. shaft, a spring holding it pressed against a spiral stop at the front of the machine. As the carriage is pressed back from left to right, the spring is wound up, the shaft is turned, and with it the spiral stop, which presses the spool along the shaft also.

The Yost Machine.—The Yost is the only machine of its class which does not use a ribbon ; a pad is used instead. This is a circular piece of felt, saturated with ink, which fits the circumference of the machine disk. When at rest the type bars stand in a vertical position with the type faces resting on the pad. There is no attempt at alignment, as the type are forced to a common printing point by means of a perforated diaphragm, having a flaring opening which draws to a center the size of the type shank. The type bars have what is known as the "grasshopper motion," and are operated by levers of the first class. The action is a complicated one, three additional levers being necessary, one of the second class and two of the third.

The Franklin.—This is a type-bar machine which prints with a downward stroke ; thus the writing is visible without any movement of the paper carriage. There is a direct connection between the levers and type bars, which are cog-geared. Teeth at the end of levers of the first class engage similar teeth on the type bars, so that the bars are forced down by a rolling motion. The machine has two type on a bar, the upper-case letters being

printed by means of an auxiliary shift. Type-bar guides force the type to print at a common point. There are 40 keys, which can be modified by the shift, printing 80 characters. The machine has a circular keyboard, radiating from the common printing point.

II. THE TYPE-WHEEL MACHINE.—*The Hammond.*—This machine, Fig. 4, has some features similar to the others which have been described, but stands alone as a type-wheel instrument. It has 30 keys; also two shifts, and as each shift gives a new meaning to every key, the machine will yield 90 characters. There is a common printing point at the back of the disk. The type are arranged on two type wheels, which together form the quadrant of a circle, and are arranged in three rows, the upper row containing small letters; the middle, capitals; and the lower, numbers and characters. The type wheels are arranged on a shaft which stands perpendicularly in the center of the disk, and so governed by a spring that, after being raised, it will be forcibly drawn down. Thus each row of characters can be brought into line with the printing point. The shifts are upon levers which operate a rocker bar attached to the wheel shaft. Each one has a stop, governing the height to which the wheel shall be carried. Thus, when figures are to be printed, the wheels are carried to the highest point; if capitals, they will be carried only half the height. For small letters, which are most used, they print on their normal level. Reaching across the levers beyond the fulcrum are universal bars, each of which covers half of the levers, one at one side of the machine, and one at the other. Thus, when the keys on the left are touched, the left universal bar is raised, and when the keys on the right are touched, the right universal bar is raised. Each is connected to a rocker bar, acting one upon one type wheel, and one upon the other, swinging them so that every part may be brought to the common printing point. Stems are placed in a vertical position over the levers, so that when any key is pressed, its stem will rise as a stop directly over that lever, preventing the wheel from turning past this point. As the type are placed upon the wheels to be guided by this action, each type presents itself at the right point to print when its key is pressed. The ribbon is coiled upon two spools, which are arranged upon upright shafts. Cogs upon the lower ends of these shafts engage spirals at the extremities of another shaft reaching from side to side of the machine at right angles to the uprights. The spirals work against each other, and, consequently, the spools turn in opposite directions. If one spool is tightened to its shaft, the other is loose and turns easily. To reverse the ribbon, one spool is loosened and the other is made tight. The lower shaft is turned by a universal bar above the ends of the levers, which also operates other mechanism in the back of the machine. The carriage is at the back of the machine, and works upon grooved guide wheels. Two feed rolls are held against each other by a strong spring, and are separated to admit paper by a disengaging pin. The mechanism which controls the movement is complicated, and more than a cursory description would be unprofitable. There is an escapement wheel at the back, arranged on a shaft, having at its other end a cog engaging the teeth of the rack, which in turn is connected to the main spring barrel. The spring draws the rack from right to left, and is held in check by an escapement pawl, which draws down upon it. When freed from this strain, a spring of its own draws it up, where it remains as long as the carriage spring is held in check by the escapement lever arm, but when this is removed, the next tooth of the escapement wheel engages the escapement pawl, and the spacing is accomplished. The action of the mechanism is set in motion by a universal bar operated by the levers.

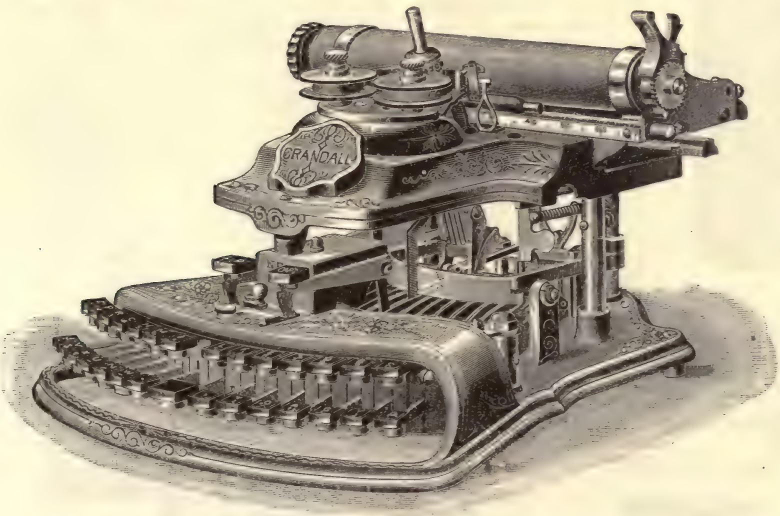


FIG. 5.—Crandall type-cylinder machine.

III. THE TYPE-CYLINDER MACHINE.—*The Crandall.*—The distinguishing feature of this

machine (Fig. 5) is that all impressions are made by the oscillating stroke of a type cylinder, Fig. 6. All printing is visible. The cylinder is actuated by means of 28 levers, together with 14 auxiliary levers. There are 28 keys. Two of them represent one character each; the remaining 26 are modified by two shifts, and so the machine produces 80 characters. The principal levers are those of the first class. The auxiliary levers engage in the differential ways on the face of a twirler, situated at the back of the machine. From the upper part of the twirler is a T-shaped arm fitted with teeth, which engage the type-cylinder gear. The type cylinder is held in a slightly inclined position upon a spindle, supported upon a bracket attached to the frame of the machine. In printing, the type cylinder is thrown into a perpendicular position against the face of the platen at a common printing point. By the depression of any key, its levers and auxiliary are set in motion. This moves the twirler, and with it the T-shaped arm which causes the type cylinder to oscillate. At the same time a cam movement, attached to a universal rocker shaft, throws the type cylinder against the platen.

Fig. 6.—Type cylinder.

IV. One-hand Machine.—*The Merritt Typewriter.*—This machine is designed to be operated by one hand. The type stand upright, and are arranged in a movable trough, which is fitted into another so that it can be moved easily from side to side. In the center is the printing point. The type are forced through a slot at this point. Whichever type is directly under the slot is forced against the platen, thus making an impression. An index key is attached to the type trough, and the type are so arranged that each one is brought beneath the slot as the indicator is moved opposite the corresponding character. The letters and characters are arranged in front, so that those most frequently used are nearest each other. This machine has two shifts, one for capital letters, and the other for numbers and other characters. The capitals and characters are arranged on either side of a small letter, so that for one the right shift is required, and for the other the left. Unlike most of the other machines described, the carriage is not moved by a spring, but is thrust forward automatically.

These are the principal machines now on the market. One of the many requisites of a writing machine is its ability to manifold. Those having type bars are especially well adapted for this purpose, as the leverage is much stronger. In a strong, well-made type-bar machine, 10 or 15 copies can be made very readily, and by using a brass platen and double carbon, as many as 40 copies are often taken at once.

On account of the numerous parts necessary to every writing machine, all require more or less attention, and for this reason the simplest mechanism and that least liable to get out of order is preferable.

Valve : see Furnaces, Blast, and articles under Engines.

VALVES.—*The Locke Renewable-disk Valve* is shown in Fig. 1. When the valve is

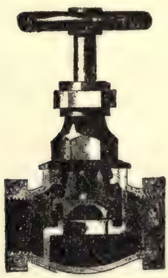


Fig. 1.—Locke valve.

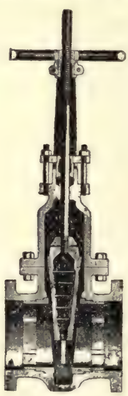


Fig. 2.—Chapman valve.

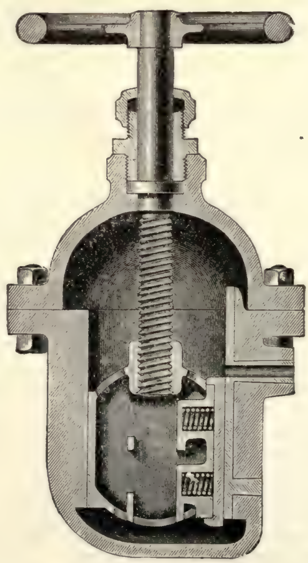


Fig. 3.—Valve with drip.

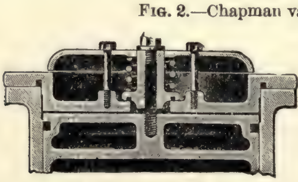


Fig. 4.—Water-relief valve.

opened enough to admit steam, the soft-metal seat is removed out of the direct line of the steam current, thus bringing the cutting action of the steam upon the cylindrical projection, or plug, instead of on the seat.

The Chapman Removable-seat Gate Valve is shown in Fig. 2. This is a valve specially designed for high steam pressures of 150 to 200 lbs. or more. It has removable bronze seats. The gate in one piece is guided closely in the body of the shell by means of ribs which take all strain. The seats are pressed into their proper positions in the body of the shell, and are held to line by means of a screw gland inserted through the pipe ends.

The Chapman Valve with Automatic Drip is shown in Fig. 3. In many cases it is necessary to drain the water from a pipe, after the supply has been cut off, by closing the main valve. To accomplish this it has heretofore been necessary to put a T into the pipe, with a valve on it, that had to be opened after the main valve was closed. The above-named valve is made with a drip opening, which is shown at the right hand of the cut.

The Spring Water-relief Valve, used on the Westinghouse steam engine, is shown in Fig. 4. The valve is made a part of the cylinder head of the engine, and has a babbitt face, resting on a seat of cast-iron. The adjustment is accomplished simply by regulating the pressure on the spring by means of the bolts provided for that purpose. When about to start the engine for the first time, the bolts are slackened sufficiently to allow each water-relief valve to puff steam at each stroke; they are then gently screwed down, thus compressing the spring, until the puffing stops.

The Ashton Water-relief Valve is shown in Fig. 5. It is used in connection with steam fire-engines, pumps, stand pipes, and hose in buildings. With it the stream can be shut off at will while the engine is working, and without increasing the pressure or bursting the hose.

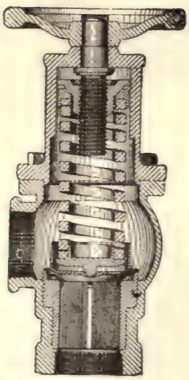


FIG. 5.—Ashton valve.

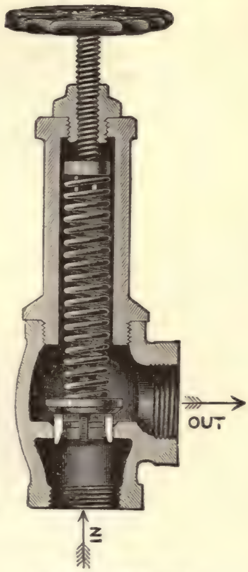


FIG. 6.—Relief valve.

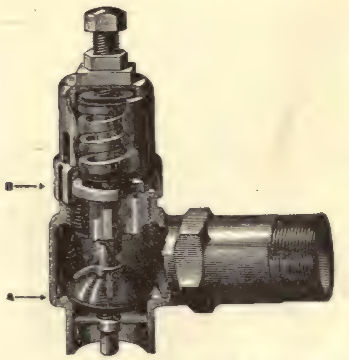


FIG. 7.—Richardson's valve.

The valve case contains a spiral spring, which, by the hand wheel shown, may be adjusted to regulate the pressure. Another form of relief valve is shown in Fig. 6. In this valve the nut is stationary, and the screw moves downward to compress the spring and increase the pressure, closing the valve.

Richardson's Combined Pressure and Vacuum Relief Valve is shown in Fig. 7. This valve is designed to be placed in the steam chest of locomotives to automatically supply to the cylinders, through the air valve, *A*, when the engine is running with steam shut off, a free supply of air from the outside instead from the smoke-box, laden with hot gases and cinders. The pressure relief valve, *B*, performs the function of preventing the dangerous accumulation of pressure in the steam chest and dry-pipe when the engine is suddenly reversed.

The Mason Reducing Valve is shown in Fig. 8. In this device an auxiliary valve, controlled by the low pressure, admits steam from the high-pressure side to actuate the main valve, which is a differential piston. The high-pressure steam enters the reducing valve at the side marked *A*, and passing through the auxiliary valve, *K*, which is held open by the tension of the spring, *S*, passes down the port marked "from auxiliary to cylinder," underneath the differential piston, *D*. By raising this piston, *D*, the valve, *C*, is opened against the initial pressure, since the area of *C* is only one-half of that of *D*. Steam is thus admitted to the low-pressure side, and also passes up the port, *X X*, underneath the diaphragm, *O O*, upon which bears the spring, *S*. When the low pressure in the system has

risen to the required point which is determined by the tension of the spring, *S*, the diaphragm is forced upward by the steam in the chamber, *O O*, the valve, *K*, closes, and no more steam is admitted under the piston, *D*. The valve, *C*, is forced to its seat by the initial pressure, thus shutting off steam from the low-pressure side. This action is repeated as often as the low pressure drops below the required amount. This piston, *D*, is fitted with a dash-pot, *E*, which prevents chattering or pounding when the high or low pressure suddenly changes.

Locke's Renewable-disk Check Valve is shown in Fig. 9. The ordinary form of check valves used in boiler feeding are liable to become leaky by being beaten out by the "water hammer," caused by the stroke of the pump. In this valve it is sought to avoid this trouble by employing a soft, renewable disk in the form of a truck (as shown in the cut), and constructing the seat of the valve with sufficient bearing surface to prevent the soft packing from having its surface ruptured by hammering on the metal seat of the valve. This is done by constructing the valve seat with arms radiating from the center, thereby supporting the packing at the center and at all points from the center to the circumference. A water cushion is thus formed, which prevents the contact of the packing with the metal seat; the

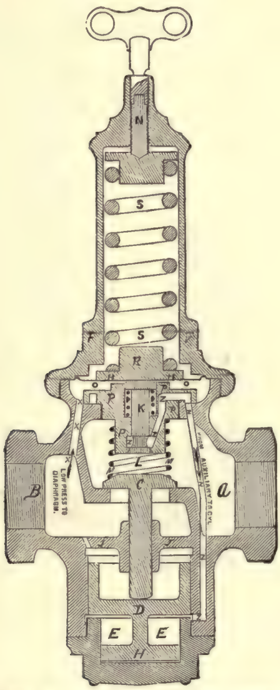


Fig. 8.—The Mason reducing valve.

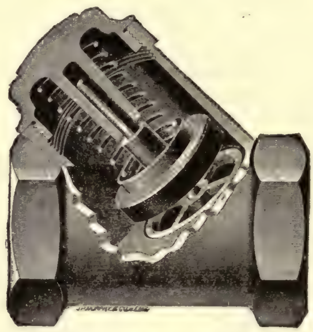


Fig. 9.—Locke's check valve.

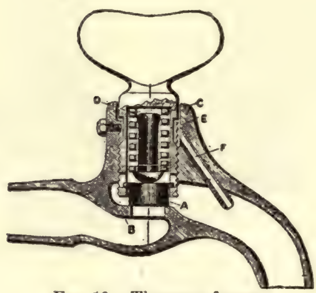


Fig. 10.—Thomson faucet.

valve really cushioning upon water, as the water has to be forced out before the parts can rest on each other.

The Thomson Faucet.—The faucet represented in Fig. 10 has recently been devised by Sir William Thomson. It is made entirely of metal. The metal valve, *A*, on reaching the seat, *B*, also of metal, is not suddenly arrested and compelled to seat itself hap-hazardly, but continues to turn on its seat as the handle is turned, receiving meanwhile a gradually increasing pressure from the spring, *C* (non-corrosive), centrally applied by the rounded head of the stop, *D*. The valve is thus rubbed upon its seat at every opening and closing, and both valve and seat acquire and maintain a perfect fit and finish. The manufacturers state that no material wear is shown on the valve and seat, even after it has been opened and closed as much as would occur in many years' service. The spiral spring has been subjected to compression 700,000 times without showing any loss in power. The cock has been opened and closed by machinery, with water flowing, 540,000 times, or the equivalent of 50 years' use at 30 times a day. At the end of the test, the valve was still tight. The method adopted to avoid the use of the ordinary stuffing-box is very ingenious. An "eduction tube," *F*, projects into the faucet opening, and sucks out any water which may collect in the chamber around the valve stem through leakage around the screw when the valve is opened. This device is claimed to be thoroughly effective.

(See Governors; Engines, Steam; and Regulators.)

Vanner: see Ore-dressing Machinery.

Vats: see Mills, Silver.

VENDING MACHINES. These are more commonly known in the United States as "nickel-in-the-slot" machines—the name arising from the fact that in the earlier apparatus first put into public use a five-cent nickel piece was required to operate them. They are all constructed so that on the insertion of some definite coin in a locked receptacle some object will be released and made accessible to the payer, or else some information, as, for example, his height, weight, or lung power will be exhibited. The applications of the idea are endless. The invention of the machine dates from the time of Ctesibius, about two centuries before the Christian era, and the first application was to the sale of measured amounts of holy water at the doors of Egyptian temples. (See Ewbank's *Hydraulics;* also Hero's *Spiritalia*, Woodcroft's translation.) Its latest development is to the automatic taking of photographs. (See *Scientific American Supplement*, December 21, 1889, and May 30, 1891.) A large collection of nickel-in-slot machines will be found described and illustrated in *Scientific American Supplement* for April 11, 1891.

The Everett Weighing Machine is the type of apparatus of this character in most common use. It may at the present time be found in all public places throughout the country. It is an automatic weighing machine. Its construction is such that when the person to be weighed steps on the scale platform, the descent of the latter sets a stop in a certain position. When a coin is inserted in the slot, a lever is tilted, working independent mechanism, which controls an index moving over a dial marked to indicate weight. The dial mechanism is limited in the extent of its operation by the stop which the weight of the person adjusts, as already stated, in definite position. Therefore, by the coaction of the two practically independent mechanisms, one actuated by the coin, and the other by the weight of the user, the range of movement of the index is so limited as to cause it to stop on the dial at the proper indication. A full description of this machine will be found in U. S. Patent No. 336,042, February 9, 1886.

VENEER CUTTING is done in three ways; first, by saws, which, of course, waste in kerf a very large proportion of the stock, the greater proportion being in the case of those woods which, by reason of their costliness, are made into the finest veneers; second, by knives which slice the material into sheets as wide as the width of the log; and third, by knives which turn from the log a ribbon of any desired thickness, as wide as the length of the log, and as long as desired. In the latter case, of course, the natural pattern of the wood, as we understand the pattern, is lost, although as a matter of fact the pattern left by the ribbon-turning machine is as natural as any other, the tree presenting to us, in its natural state, neither the one class nor the other of grain pattern.

In veneer-turning machines, the log, say, in sections 48 in. long, is held between two live centers, and presented to the action of a slicing knife, the full length of the log, and an automatic feeding attachment brings the knife closer and closer toward the center of rotation as the stuff is removed; the distance advanced in one rotation being the thickness of the sheet pared off. In working in common stock, the machines are furnished with scoring knives to cut the stuff to length, or to mark it for bending, as for berry boxes, grape baskets, etc. Sometimes the machine has a roller with knives on its surface, for cutting stuff to width and shape. In one of the best-known rotary veneer-cutting machines, the rough log is centered between chucks and rotated against a knife which is moved forward upon a carriage, fed by screws and a suitable system of gearing. The chuck arbors have two bearings far apart. The knife has a quick-return motion, and can be stopped, advanced, or reversed by moving a lever; and there is an automatic safety attachment by which the knife stops at any desired point in forward or backward travel. In some machines there is an especially quick advance of the knife to bring it up to the cut. The desired thickness of veneers is secured by a change of feed gear, which varies the rate of rotation of the screws. The knife is set at an angle to the log, with its bevel side next to it, thus enabling the cutting edge to act at the center line or a trifle above it; and this angle is maintained down to the smallest core which can be left.

Vise: see Pipe-cutting Machinery.

Warper: see Cotton-spinning Machines.

WATCHES AND CLOCKS. WATCHMAKING BY MACHINERY.—The process now generally followed in making a modern watch is as follows: The plates, which are the foundation of the watch, are cut out by punches and dies, made specially for each design. In the main punch there are a number of small punches inserted, and so accurately placed that the exact position of the holes required to be drilled are marked upon the plate. Then they are drilled, the plates are ground flat, the edges turned, and all parts to be turned out or recessed for wheels to set in, are done on special chucks, used in a proper lathe. The other parts,

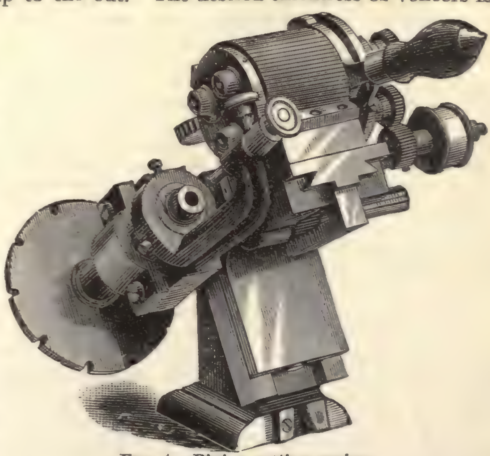


FIG. 1.—Pinion-cutting engine.

such as pillars, bridges, etc., are then fitted and the plates put together. After all the fitting is done, the parts are dismembered, and gilded, and in some instances nickeled.

The wheels are punched out in complicated dies, which act so as to perform several operations at one stroke of the press. After punching, they are placed on what is known as a wheel-cutting engine, a number of wheels—generally about 30 or 40—being put upon an arbor at one time, so that the cutter passes through the whole stack and cuts one tooth in each of the wheels at each stroke of the machine.

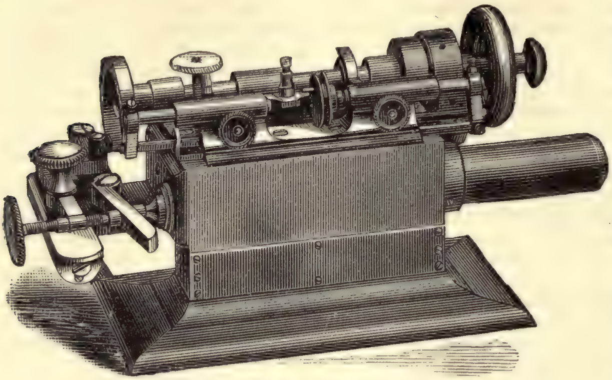


FIG. 2.—Pivot-turning machine.

After the teeth are cut, the wheels are bored, ground, and gilded or nickeled, as the case may be, after which they are ready to be staked or fastened to the pinions. The pinions are cut in suitable lengths from a steel wire by a special cutter or die, made for that purpose, operated by a press similar to that used for the plates and wheels. These wire pinions are then chucked in a lathe, and a point, or center, as it is called, turned on each end, after which they are taken to another lathe, where, by a tool carried in a slide rest, they are turned down rough nearly to size. From this the pinions are set on dead centers in an automatic pivot machine, and turned to the exact size every way ; after that the teeth are cut, and then they are hardened. After being hardened, the teeth are polished by a machine known as a leaf polisher ; then the pivots, staffs, etc., are polished with the "wig-wag," a tool well known to watchmakers and jewelers. All the parts are similarly treated, beginning with the punch and dies in the press, and pass along from one machine to another, until they are ready to be assembled in the finishing or setting up room, and put together to form a timepiece. There are about twenty different mechanical departments in a watch factory, each performing a specific operation, and their products all center in the finishing room.

The Pinion-cutting Engine, manufactured by the Gesswein Machine Co., and shown in Fig. 1, is universally used for cutting the teeth in pinions for watches and clocks. It has a revolving tool head that carries three spindles. One of these drives a saw for cutting away the stock in advance of the other cutters ; the second spindle drives a cutter to rough out the shape of the tooth, and the third spindle operates the finishing cutter, which gives the form to the teeth. The operation of this machine is simple and rapid.

The Automatic Pivot-turning Machine shown in Fig. 2, a very ingenious piece of mechanism, also made by the Gesswein Machine Co., is for turning the staffs and pivots on all pinions, pallet arbor, etc. The wire is pointed and rough turned in a No. 2½ lathe ; it is then placed on dead centers in this machine and turned very accurately to a length from shoulder to shoulder, and also in diameter. The turned staffs and pivots are then hardened, and after hardening, are ground and finished on the "wig-wag" machine.

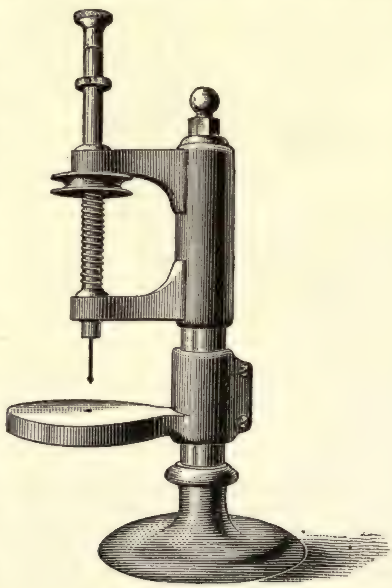


FIG. 3.—Upright drill.

The form of upright drill which is mostly called into use in the manufacture of the several parts of watches and clocks is that shown in Fig. 3. The spring action of the drill stock makes it specially serviceable for this fine work, and in the drilling of plates, bridges, etc. Fig. 4 shows a screw-cutting machine of the Gesswein Co.'s make, largely used in watch manufacture. A wire is fed forward through the chuck, which projects between two movable cutting heads, and the tail stock has a horizontal screwed rod which acts as an adjustable stop for the end of the wire, in determining the length of screw to be cut. One of the slide rests or heads carries the thread-cutting tool, and the other, the cutting-off tool. This figure also shows a detached view of a tail stock for the same machine, with multiple stop

spindles, to be used when it is desired to cut different lengths of screws without changing the tail stock.

Stem-winding Mechanism.—Although the manufacture of key-winding watches has been discontinued entirely, and only stem-winding watches are now made, these attachments are still much in demand, in connection with American watches such as the Waltham, Elgin, Hampden, Illinois, Rockford, Cornell, Howard, etc. English, Swiss, and other foreign watches, being largely made by hand instead of machinery, the parts are not interchangeable, and consequently cannot be converted ordinarily by the same devices.

A novel stem-winding attachment for watches has been devised by Mr. Henry Abbott, of New York City. It is designed to be applied to key-winding watches already in use, so as

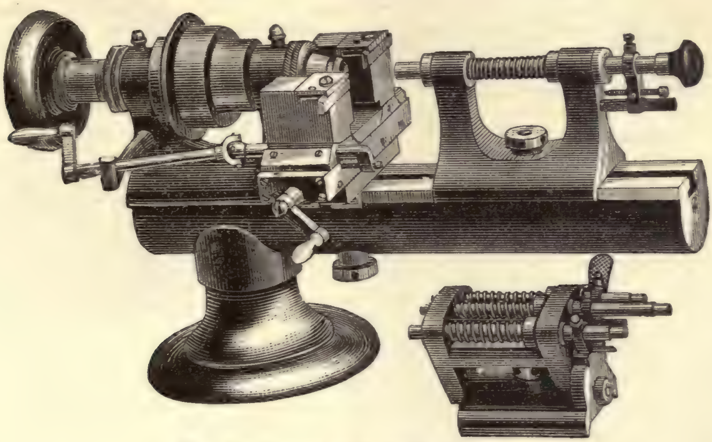


Fig. 4.—Gesswein screw-cutting machine.

to convert them into stem-winders. The attachment is manufactured by the same kind of machinery and in the same manner as stem-winding watches, and when properly fitted, the watch is to all external appearances, and to all intents and purposes, the same as if made originally as a stem-winder.

Fig. 5 shows the attachment itself, and Fig. 6 presents it combined with a Waltham movement.

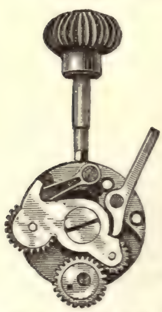


Fig. 5.—Stem winder.

The pendant of the watch is usually removed, and one suitable for the new winding stem and crown substituted. The stem projects within the case, and carries on its end a small beveled winding pinion, which meshes with a crown wheel pivoted between two plates, one called the main plate and the other the yoke; the upper or yoke plate is of an elongated shape, and mounted so that it may be rocked upon a pivot. On either side of the central screw or pivot the yoke carries pinions or gear wheels, both meshing with the crown wheel, one (called the intermediate winding wheel) being somewhat larger than the other, on account of its having heavier work to do, viz.: the winding of the watch through its engagement with the main winding wheel. The other wheel, carried by the pivoted plate, is called the intermediate setting wheel, and this is thrown into contact with a hub wheel by means of the setting lever acting upon a cam edge of the pivoted yoke; the hub wheel is in mesh with the pinion on the hand spindle or central arbor. A V-spring acts against the yoke to keep the intermediate winding wheel in contact primarily with the main winding wheel. The same spring forms the ratchet when the winding crown is turned backwards.

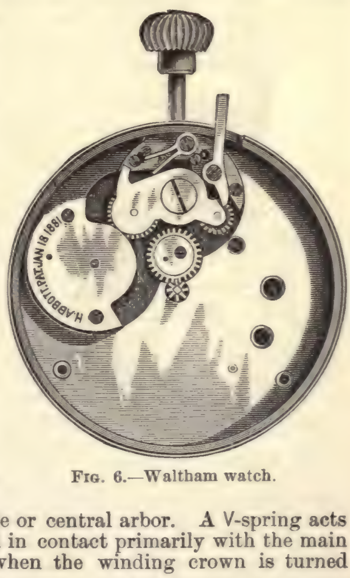


Fig. 6.—Waltham watch.

The Abbott stem-winding attachment for Howard watches, while necessarily somewhat different in construction from that used in Waltham watches, embodies the same essential characteristics, viz.: that it is complete in itself, and is assembled and fitted with its several parts connected in their combined operative position, ready to be placed in the watch by the

watchmakers to whom the attachments are sold. Fig. 7 is a view of this attachment looking at its underside, and Fig. 8 represents a Howard watch embodying the same. Upon the winding stem, in addition to the winding pinion which meshes with the crown wheel, is carried (upon a square portion) a sliding double-clutch wheel, acted upon by a spring to keep it normally up to engagement with a clutch on the lower side of the above winding pinion. This is the normal position, and the one occupied by the parts for winding the watch. The movement of the setting lever causes the spring to act in the reverse direction, thus throwing the sliding clutch downward so that the lower teeth of the latter will mesh with one of two intermediate setting wheels, the latter of which meshes with the first and engages also with the usual minute wheel, which meshes with the ordinary cannon pinion, on the end of which is mounted the minute hand. Over the cannon pinion is placed the hour wheel, carrying the hour hand as usual. The parts being in this position, the hands can be moved.

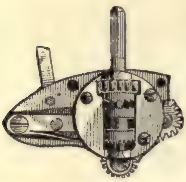


Fig. 7.—Attachment.

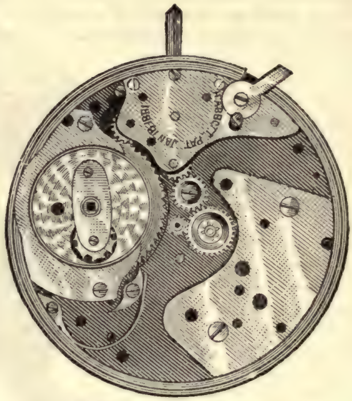


Fig. 8.—Howard watch.

Marking Dials.—An ingenious invention of Mr. Abbott is the new method of marking the numerals, divisions, letters, and ornamentations upon watch dials, which is controlled and largely used by the Elgin Watch Co. The process does away with all painting or marking by hand upon the dial itself. The blank dial plate is made up as usual of a copper base coated with enamel, and the design for the face is first engraved upon a steel or copper plate. This is coated with the ordinary vitrifiable pigment, and allowed to dry; then the surface of the plate is brushed off, leaving the filling intact. A layer or coating composed of a preparation of collodion is now laid upon the entire surface of the plate, and this permeates and goes down through the filling of pigment, and practically covers the underside of the pattern. Evaporation causes the formation of a film on both sides, with the pigment lying between, and by this means the complete pattern intended for the dial plate may be cleared from the engraved matrix, preserving even the very finest lines intact. This is accomplished by immersing the engraved plate in a bath of acid and alkali. The film floats off, and, being somewhat soft, it readily sticks to the dial plate upon which it is now placed, and after baking as is usual with enameled plates, it is found that the collodion film has been burned off, leaving the pigment (the whole pattern) permanently incorporated with the dial plate.

The Waterbury Watch has probably taken first place in the category of cheap timepieces. It is extremely simple, being made up of less than one-half of the number of parts usual in a watch, and these are so arranged as to be easily cleaned or repaired. The great differences between this movement and others are that it has a long, thin mainspring (nearly four times the length of an ordinary watch spring), and that the entire movement revolves in the case once every hour, and thus regulates or adjusts itself to varying positions. The use of the long mainspring is consequent upon the reduction in number of parts; there is no barrel used, and two wheels and their pinions are also dispensed with in the train, which places the power direct upon the escapement. The latter is of the duplex pattern, and is very light running; it has only two pieces, the balance and escape-wheel. There is a stop work to prevent damage from overwinding at the stem, and all the parts are made interchangeable.

Fig. 9.—Waterbury watch.

Fig. 10.—Regulator.

The case of this "long-wind" watch is stamped out in only two pieces, and nickeled. To set the hands, it is necessary to remove the bezel entirely, and use a point, or the finger, in this operation, as well as in adjusting the regulator, which is approached from the front. Fig. 9 is a view of this watch with the bezel off, and Fig. 10 represents the regulator and part of the movement.

The Waterbury Watch Co. is also making cheap "short-wind" watches, with cases of nickel, coin silver, oxidized silver, and gold filled, and of several sizes and various designs. Fig. 11 shows the working parts of this "short-wind" watch, the balance wheel,

the independent bridge, the tempered hairspring, back ratchet, etc., as well as the winding parts. The "wind" is simple, being composed of only five pieces. Both the pillar and top plates are made double, which arrangement holds the winding work and jewels in position, and takes the place of the ordinary bridges, screws, etc.

Fig. 11.—Waterbury "short wind" watch.

Recent Improvements in Watch-making.—The Waltham Watch Co. introduced a novel improvement in the movements of their make a few years ago, which has helped to offset any damage done to the train following the breaking of the mainspring. The center pinion is removably fixed to the center staff; the pinion has its axial hole screw-threaded to correspond with a similar thread upon the staff, the direction of thread being such that the strain of the mainspring, acting through the teeth of the barrel upon the pinion, will force it against a shoulder formed for the purpose on the staff, making it practically a single piece; but should the mainspring break, the violent recoil of the broken spring would simply serve to unscrew the pinion from the staff without harm to either, instead of having the effect of breaking the teeth of the barrel and pinion.

The Non-Magnetic Watch.—The Waltham Watch Co. has recently perfected and put on the market the non-magnetic watch, the result of expensive experiments since 1887; such watches being especially valuable to electricians and other persons liable to go near dynamos, electric car motors, and the like. This achievement in modern horology has been accomplished by substituting for steel as used in the balance, roller, hairspring, and pallet and fork (which together constitute that portion of the watch designated as escapement), metals or alloys which are non-magnetic, and which yet possess the properties of elasticity and expansion to such relative proportion as to enable them to compensate for the varying conditions of heat and cold.

How difficult a problem this has been to solve may be imagined when it is considered that no single known metal possesses all the qualities required. And, further, that each of the different portions of the escapement requires to be constructed of metal having certain characteristics which shall fit it for the peculiar duty of that part, and which may not be demanded by some other part.

There are, however, two requisite properties common to all the parts: First, sufficient ductility to be capable of being brought into the required form; second, non-susceptibility to magnetic influence. The function of the fork demands a metal able to withstand wear; the hairspring must possess elasticity in a high degree, and yet must be capable of being fixed or "set" in proper spiral form.

The duties of the balance require that its body be made capable of a certain degree of expansion under the influence of heat, but it must not be too expansive; while the outer lamina of the rim must have a very high ratio of expansion, without undue rigidity.

Clocks.—*Recent Improvements.*—Clocks have recently been combined with dating stamps, for use in banks and in city and court offices of record, by which the letters and papers filed are not only marked with the day, month, and year, but the hour and minute of the day the papers were filed.

Outside of the automatic novelties known as the swing clock and the jumper clock, the improvements in clocks have been limited to various different constructions of the parts. Among these various improvements may be mentioned the Blakesley clock, which employs in lieu of the usual pallet a worm engaging with the escape wheel, the worm shaft having an arm so connected with the pendulum as to impart a rotary movement thereto.

The late Henry J. Davies, so long connected with the Ansonia Clock Co., made many improvements in that particular class of goods put on the market by the Ansonia Co., among which may be mentioned a construction in which the main wheel of the clock has attached to it the inner end of the mainspring, which is arranged in concentric relation with the center arbor of the clock. The clock case has a loose back or back piece, having attached to it a rigid ratchet adapted to rotate freely around the main wheel arbor when winding up the clock, and having one or more clicks to prevent the back motion of the mainspring. The main arbor also was tubular, and through this extended the minute-wheel arbor, having a key at its end for the adjustment of the hands from the rear of the clock.

Another form of the escapement is that invented by Edmond Kuhn, which employs a

pinion cap having four arms, which, upon rotating, successively strike the escapement wheel to rotate it as usual.

Another novelty is a clock made by the New Haven Clock Co., which employs two pendulums suspended on trunnions vertically in line, and connected together by pinions which transmit a reverse oscillating movement from one to the other, one of the pendulums being connected with the anchor of the escape movement.

A different form of escapement lever, the invention of Mr. Bannatyre, is made by the Waterbury Clock Co., which has an impulse fork at one end, a bank fork at the other end, and with a laterally projecting ear upon each side between the forks, said ears being formed integral with the lever. The lever has two pallet pins, made wedge-shape in cross section, and the ears are constructed with holes of corresponding wedge-shape, into which said pins are forced.

A novel method of making hairsprings for balances was invented by Mr. Logan, of Waltham, Mass., which consists in simultaneously coiling two parts of a piece of wire around a suitable snail or former, beginning at a ligature which constitutes the central portion of said piece, thereby converting the said two parts of the single piece of wire into two coils, which are integral with each other, their inner ends being connected by the ligature. These two coils are then hardened, in the usual manner, while their ends are yet connected, and are finally separated to complete the springs by severing the ligature. This is said to be a very efficient and cheap mode of making hairsprings.

A further improvement in an escapement for timepieces was made by Mr. Hansen, in which the balance wheel has a spring for imparting motion to it in one direction, and a spring-actuated lever for imparting motion to it in the other direction, the lever being provided at one end with a pallet for engagement by the escape wheel, and with a hook at its other end, and a locking pin for effecting the disengagement of the hook and pin, which thus permits the passage of a tooth of the escape wheel and allows an impulse to the balance wheel.

A clock-winding mechanism, which permits the train to continue its movement while the mainspring is being wound, consists in winding the spring from the outside through the barrel instead of through the arbor.

One of the smallest lantern pinions probably made is that now used in some of the cheaper forms of clocks, in which the staff has two collets, one of which is constructed with a circular series of perforations and the other with a series of corresponding seats. A series of leaves extend through these perforations of the one collet into the corresponding seats in the other collet, and a cap is mounted on the staff so as to bear directly against the outer face of the perforated collet, which thus prevents the leaves from becoming displaced.

In a clock called the "Independent Electric Clock," in which the electrical movement is entirely independent of the ordinary pendulum movement, there is combined with the escapement a spring for turning the escape wheel, a ratchet and pawl for winding up the spring at intervals, the usual hands, and an electro-magnet for actuating the pawl of the winding spring and for moving the minute wheel step by step.

Another very important improvement is in arranging a single spring to drive the train as well as to operate the striking mechanism, which is made by the Waterbury Clock Co., and in this clock it is impossible to disarrange the striking mechanism so as to make it strike falsely. The clock may be turned to any extent backward, and when moved forward will strike correctly the half hours as well as the hours.

WATER METERS. *The Thomson Water Meter* is shown in Fig. 1. The displacing or measuring member consists of a flat disk, having a ball-and-socket bearing, and is adapted to oscillate in a chamber, comprised of two sections joined together, in which each of the inside faces approximates the frustum of a cone, the exterior confining wall assuming the form of a circular zone. The disk has a single slot projecting radially from the ball, which embraces a fixed metallic diaphragm, set within and crosswise of one side of the chamber, the disk being thus prevented from rotating; but when it is caused to oscillate in contact with the cone frustums, the chamber, by these means, is divided into sub-compartments, or measuring spaces. Now, if the ports of ingress and egress are properly disposed on opposite sides of the diaphragm, the disk will act as its own valve. The course of the flow through the meter is as follows: Entering the compartment, formed by the upper and lower caps, the current passes on all sides of the chamber, to and through the inlet port; thence through the measuring chamber (causing the oscillation of the disk), then through the outlet port, to the outlet spud and the pipe. At all sections in this path, from the inlet to the outlet, the velocity of flow is much less than that through the pipe. The oscillation of the disk produces in its central axis, at a right angle to the plane of the disk, circular motion. Advantage is taken of this to control its proper relative action in respect to the cone frustums, by mounting a conical roller upon a spindle fixed in

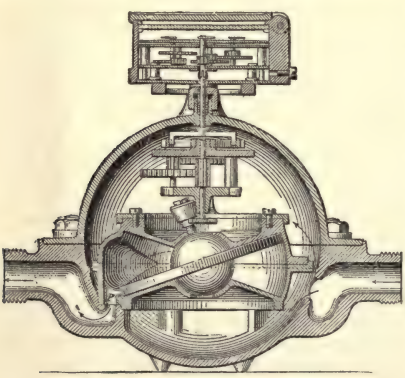


FIG. 1.—Thomson water meter.

the ball. This roller impinges upon and rolls around the fixed conical stud or hub, formed on the inner side of the gear frame. The roller turns upon a conical sleeve which is screwed upon the disk spindle; the object of this construction being to avoid any tendency to produce end-thrust, consequent upon the angular thrust of the spindle, and also to provide means whereby to obtain the proper relative adjustment between the disk and the cone frustums. The accidental displacement of the adjusting sleeve is prevented by inserting a pin through its shoulder and also the body of the spindle, which is then bent, each end at a right angle to the other, to lock it in place. This circular motion of the spindle is also utilized to drive the registering mechanism by means of an arm secured to the primary pinion of the train; the arm impinging upon and being driven by the lower extension of the roller. The trend of the motion of the disk is to thrust the edge of the slot constantly against the outlet side of the diaphragm.

The diaphragm is made of hard rolled metal, which is shaped very accurately, and is rigidly secured between the two sections of the disk chamber. The internal gearing which connects the disk to the stuffing-box spindle is mounted between two separate plates secured together by pillars, as in clocks, and, in the smaller sizes, the whole as a single structure is secured by screws directly to the disk chamber. The gearing stands in the upper portion of the compartment, and is thus out of the direct path of the current.

The Venturi Meter, made by the Builder's Iron Foundry, Providence, R. I., is shown in Fig. 2. It is the invention of Mr. Clemens Herschel, and was first described by him at the December, 1887, meeting of the American Society of Civil Engineers. Its action is founded on the well-known property of a Venturi tube to exercise a sucking action through holes bored into its narrowest section. The construction of the meter, as shown by the accompanying cut, is merely a contraction of the main pipe, to which two ordinary pressure gauges are connected—one at any convenient point before contraction of pipe begins; the other at the smallest section. When any flow in the pipe occurs the pressure on throat gauge will fall, if the flow becomes sufficiently rapid, all pressure at the throat may disappear and a vacuum obtain. The other gauge, however, will continue to indicate the pressure due to the supply. By mathematical calculation and experimental confirmation, a formula, based on the different pressures on the gauges, has been obtained, which accurately indicates the velocity of flow through the throat of the meter. An ordinary self-recording differential gauge may be used to obtain a diagram of these variations in pressure, from which both the velocity at any given time, and the total quantity passed in any interval, may be readily determined.

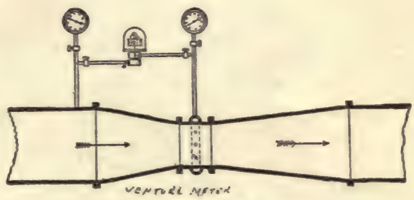


FIG. 2.—Venturi meter.

Water Tower: see Fire Appliances.

WATER WHEELS. The old "outward flow" and "inward flow" turbines have practically given place to the "inward and downward flow," as outlined by the Swain wheel (see APPLETON'S CYCLOPEDIA OF APPLIED MECHANICS); but the change from that wheel to those of less diameter, with deeper buckets, of longer curve, has been very decided, and resulted in higher efficiency, as well as greater economy in first cost. The following comparison illustrates this point.

Wheel.	Diameter.	Revolutions per minute.	Cubic feet water per minute.	Horse-power.
Boyden	36 in.	161	1,207	34·2
Swain	30	197	2,124	65·5
Risdon, "D. C."	30	210	2,959	95·
Victor	30	183	3,580	115·
Hercules	30	174	3,960	119·6

The Risdon Wheel.—The foregoing figures are taken from the published catalogues of the wheels, and are probably closely correct, although there is a discrepancy in the velocities. The *inward* portion of the discharge has been practically abandoned, the buckets being closed down to the bottom on a central core, and so curved as to throw the water out from the centre, as shown in Fig. 1 of the Risdon "D. C." or "double capacity" wheel mentioned above. This form of bucket appears to take advantage of the centrifugal motion given to the water by the wheel itself, and which in the case of the (original) inward discharge was directly opposed to the effect of the water.

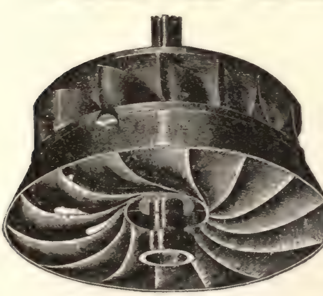


FIG. 1.—The Risdon wheel.

Another cause of the displacement of the "outward discharge" wheel was the very poor result obtained at "part gate," or when the water was cut off by a sharp edged cylinder, or register, gate. Placing the gates

externally has enabled them to be so formed as to deliver the water in an unbroken volume, by ajutages which contract the flow, instead of cutting it partially off.

Thus, while the Boyden dropped from an efficiency of 79 per cent. at full gate to 44 per cent. with half water; and the Houston from 81 per cent. to 23 per cent.; the "Risdon" falls from 87 per cent. to 70 per cent., and the "Hercules" from 87 per cent. to 74 per cent., in Professor Thurston's best test. The Risdon wheels at the Jefferson mill of the Amoskeag Manufacturing Co., Manchester, N. H., consist of two pairs of 43-in., and one pair of 36-in. "D. C.," as shown in cut of bucket, and are all mounted on a 9-in. steel

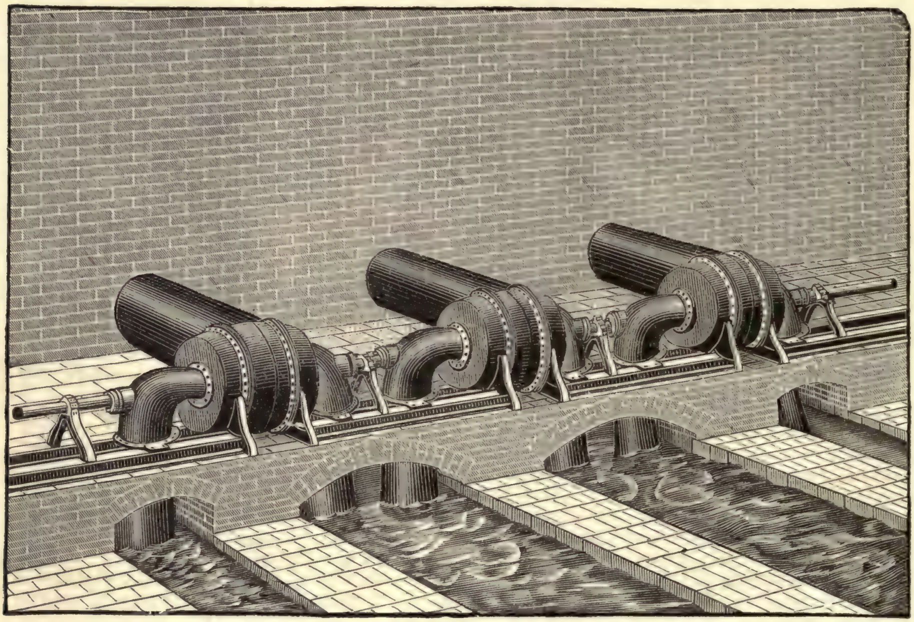


FIG. 2.—The Risdon wheels at the Jefferson mill.

shaft, with couplings between the 43-in. and the 36-in., so that the latter, which draw water from a lower level, can be disconnected if desired. The head on the 43-in. wheels is 49 ft.; that on the 36-in. ones is 28 ft., giving them the same circumferential velocity at 225 revolutions per minute.

Fig. 2 illustrates one of the most complete systems of horizontal-shaft turbines yet introduced, *viz.:* that furnished by the Risdon Co. (previously described) for the Jefferson mill of the Amoskeag Co., at Manchester, N. H. It consists, as shown, of 6 wheels, in 3 pairs, on one shaft; one pair, under a lower head, being of smaller diameter, so as to have the same surface velocity, or 62 per cent. of that due to the head.

These wheels themselves are all solid bronze castings, but the cases and draft tubes are cast-iron, and the feeder pipes boiler plate. Six small wheels were here adopted, in place of three large ones, as first suggested, to obtain higher velocity of shaft, smaller driving pulleys as a consequence, and the ability to use as large a proportion of the very variable quantity of water to the best advantage, or as near "full gate" as possible.

The Collins Wheel.—A form of gate, similar in effect to that used on the Fontaine turbine, exhibited by Messrs. Froment, Meurice & Co., in London, in 1851, and which may be called a "plunger gate," is used on the Collins "downward flow" turbine shown in Fig. 3. This form of gate raised the efficiency of the Collins wheel to 85 per cent. at full gate, and 66 per cent. with 0.565 water, which Professor Thurston says is the best performance of a Jonval turbine on record.

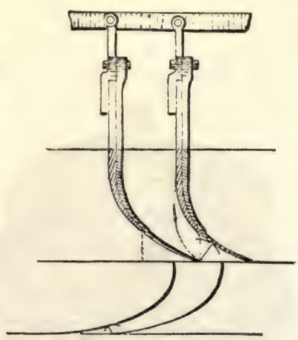


FIG. 3.—The Collins wheel.

Another well-known form of the Jonval turbine is the "Geyelin," built by Messrs. R. D. Wood & Co., of Philadelphia. One of these wheels, as tested by the writer, at the Centennial Exposition in 1876, gave over 84 per cent. net effect, and practically the same result was obtained from a 7-ft. wheel of the same style

at the John P. King mill, at Augusta, Ga., 475 horse-power having been realized by the last test. All this type of Jonval wheels give high results at "full gate," but are somewhat defective at "part gate."

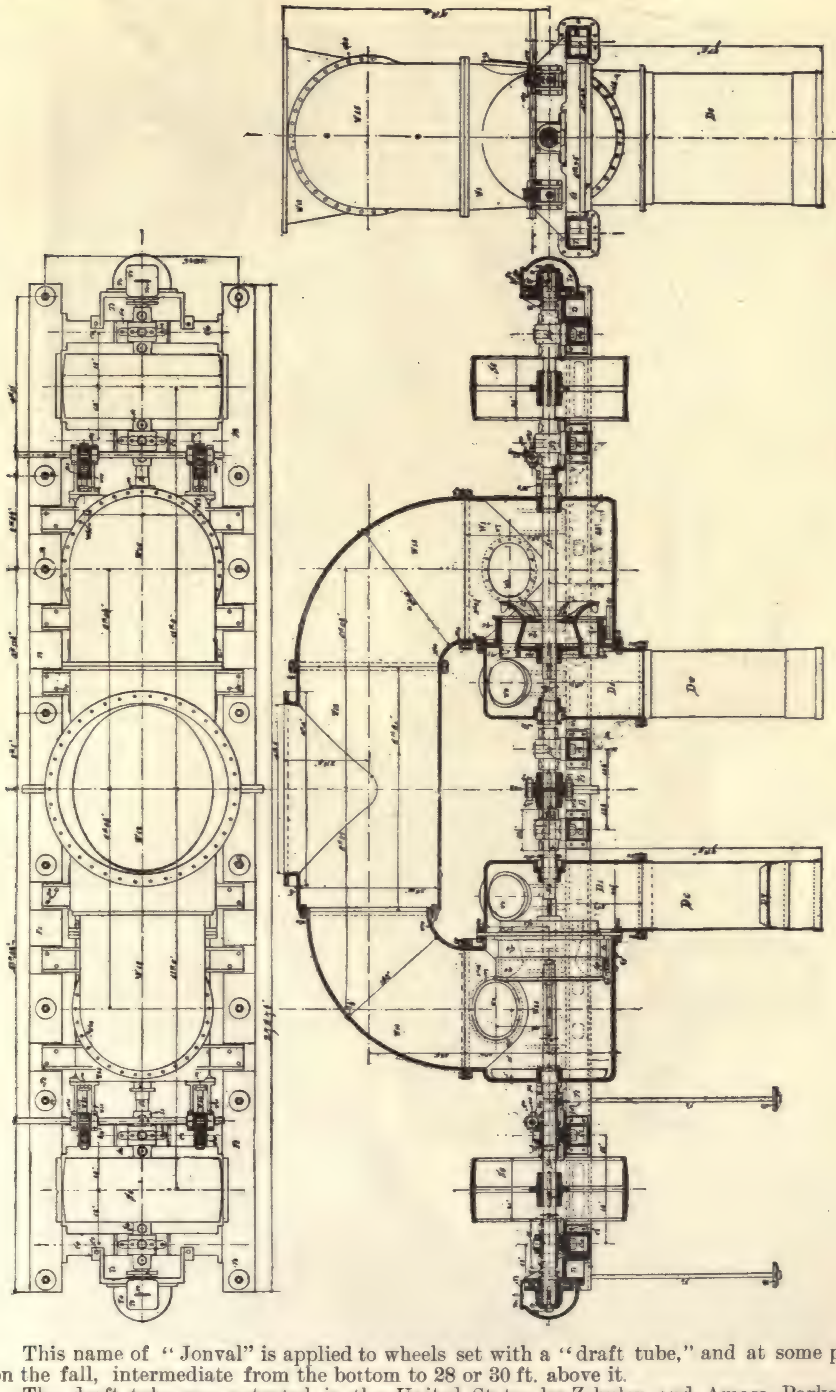


FIG. 4.—Geyelin turbines at Cornell University.

This name of "Jonval" is applied to wheels set with a "draft tube," and at some point on the fall, intermediate from the bottom to 28 or 30 ft. above it.

The draft tube was patented in the United States by Zebulon and Amasa Parker, of Licking, O., in 1840. It has proved of great value, by enabling turbines to be set on horizontal shafts.

Figs. 4 and 5 illustrate the construction of the Geyelin turbine constructed for Cornell University, by Messrs. R. D. Wood & Co. The turbines are 34 in. in diameter, and are calculated to produce 175 horse-power at 40 ft. head. Their speed is 253 revolutions per

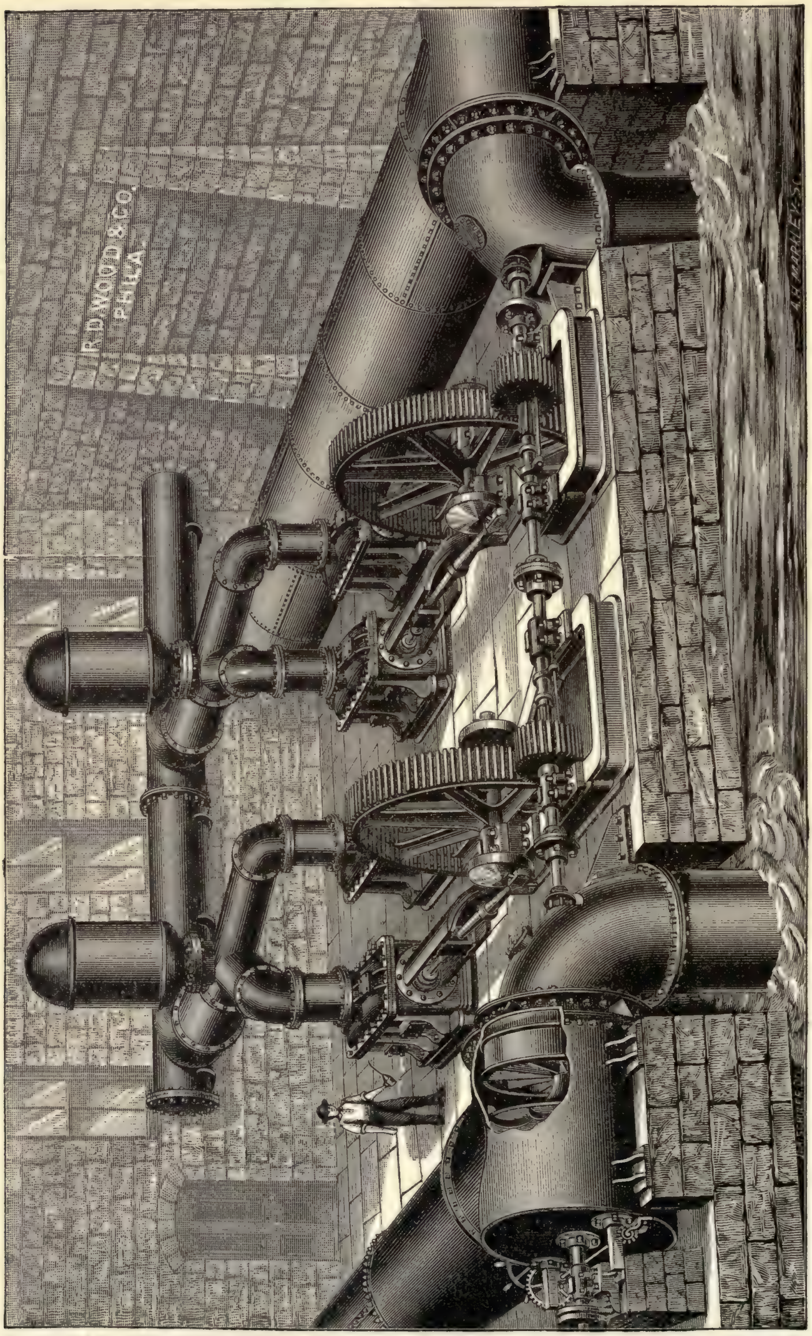


Fig. 5.—Geyelin turbines at Cornell University.

minute. Mr. Geyelin has devised a novel and effective form of glass suspension stop, which is illustrated in cross section in Fig. 6. The revolving disk, *A*, which supports the wheel, rests on the glass disks, *B B*.

The Hunt Wheel has since been improved by the addition of "ajutages" to the gate, bringing the half-water effect up to 66 per cent. These "ajutages" are shown in Fig. 7, appearing between the chutes. The next great step in turbine construction has been to set them on horizontal shafts, and, when practicable, in pairs, so as to thrust against each other, and neutralize step friction.

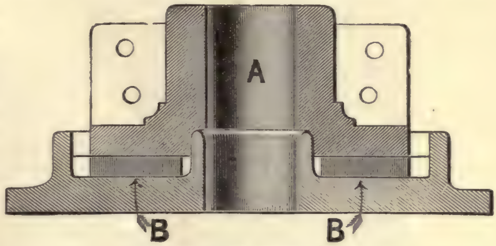


Fig. 6.—Glass suspension step.

Glynn, in his *Treatise on Water Power* (John Weale, 1853), speaks of this method as being advised by Professor Wedding, of Berlin, for the Archimedian scroll wheels, to save step and gear friction. About 1861, the late John C. Hoadley put in a scroll wheel of this sort, in Manchester, N. H., and the writer followed it within two years later by seven small iron turbines, set in iron pipes, singly, and in 1876 the Swain Turbine Co. put in a pair of wheels in this manner at Ticonderoga, and the plan is now adopted by all prominent turbine builders.

Fig. 8 shows the external case of a pair of Hunt wheels set in this manner with central draft tube. This method of setting saves not only the cost of bevel gears, but the loss of power by their friction, commonly estimated at about 5 per cent. Two tests of a Hunt wheel, at the Holyoke testing flume (on vertical shaft), by Mr. Herschel, gave respectively ·8006, and ·8043 per cent. effect, and the same wheel, on horizontal shaft, in the mill at Lowell, was tested by Mr. Francis, giving ·8030 and ·8036 per cent.

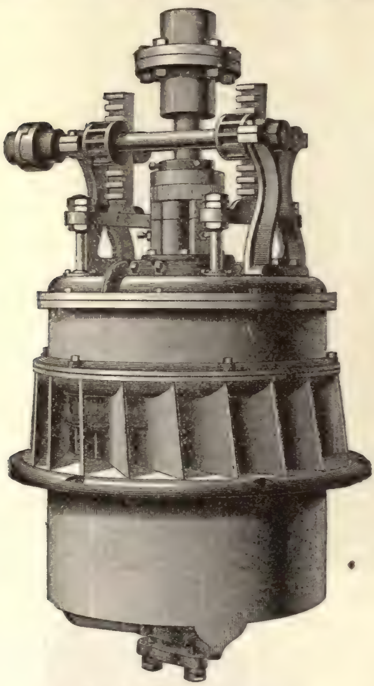


Fig. 7.—The Hunt wheel.

The Humphrey Wheel has a "paraboliform curve of crown and chutes," so as to deliver the water to the wheel in a tangential direction, and also in the natural form of discharge due to the "vena contracta." The buckets are not closed down to the bottom on the outside, but have a free outward delivery, as seen at *K*, Fig. 9. Another point claimed is the reduction in number of the guides or chutes, thus saving friction, before the water reaches the wheel itself, and offering less obstruction to the passage of small floating matter, such as leaves or sawdust and chips. The discharge of water from any wheel should be such that its total velocity should be imparted to the wheel, and that the water should fall away "dead," thus doing away entirely with the theory of any result from "*reaction.*" The writer has obtained the best results, from nearly all the wheels which he has tested, when the velocity of the wheel at the point of central discharge was from 60 to 62 per cent. of the theoretical velocity due to the head, or to the velocity due the "contracted vein." A very large wheel of this type, 100 in. diameter, using 214 cub. ft. water per second, under 12½ ft. fall, tested by Mr. Francis, at Lowell, in 1883, gave over 240 horse-power, or about 82 per cent. net effect, at full gate, and 56 per cent. with half water, or 40·06 per cent. gate opening.

The Victor Turbine, built by the Stilwell & Bierce Co, of Dayton, O., is a popular and effective form of the latest modern turbine, with deep openings, and long curved buckets, discharging downward and outward. Fig. 10 represents the wheel separately.

Reliable tests of the Victor wheel show an efficiency of from 80 to 89 per cent. at full gate, the higher effect being obtained from a very small wheel, 15 in. diameter, this being the usual result from all forms of turbine. The efficiency at one-half water, which must be distinguished from "half gate," is about 50 per cent. with the register gate, but a cylinder gate with ajutages is promised on this wheel. To show the power and effect of one of these small wheels, we give a record of tests of a 15-in. Victor, made a few years since at the Holyoke testing flume, in the course of some experiments to determine the friction of gearing. The wheel had been tested on its own shaft previously, by James Emerson, giving a net effect of 92·58 per cent., or 30·62 horse-power, at 348·5 revolutions per minute, and these tests show a loss of about 3 per cent. due to the gears.

Other tests, which it is unnecessary to tabulate here, showed that by changing the position and contact of the gears, this loss at times might be fully 10 per cent.

In these tests, the velocity of the external surface of the wheel was from 68 to 70 per

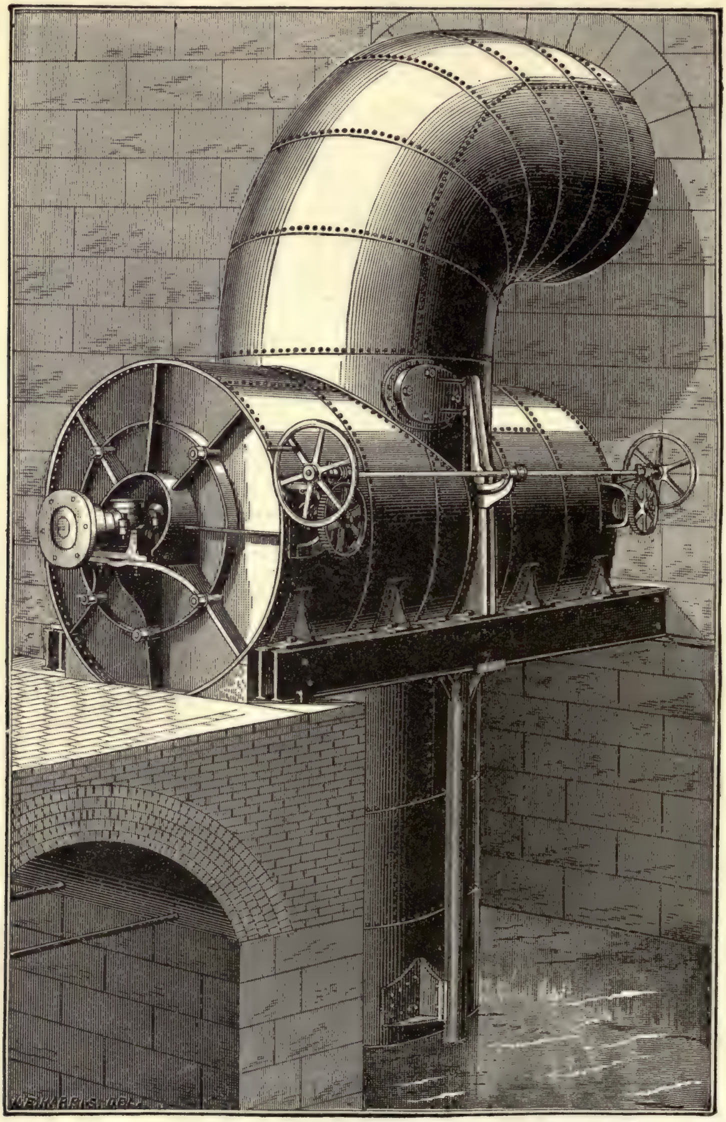


FIG. 8.—Hunt wheel case.

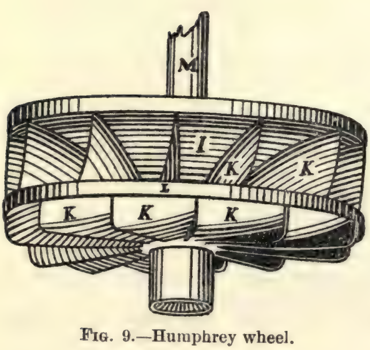


FIG. 9.—Humphrey wheel.

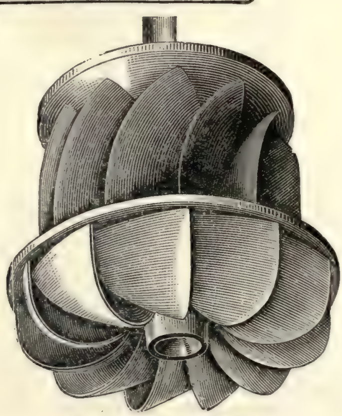


FIG. 10.—Victor wheel.

cent. of the theoretical velocity of the water. From the shape of the bucket, it is difficult to ascertain the velocity at the point of maximum discharge, but it appears to have

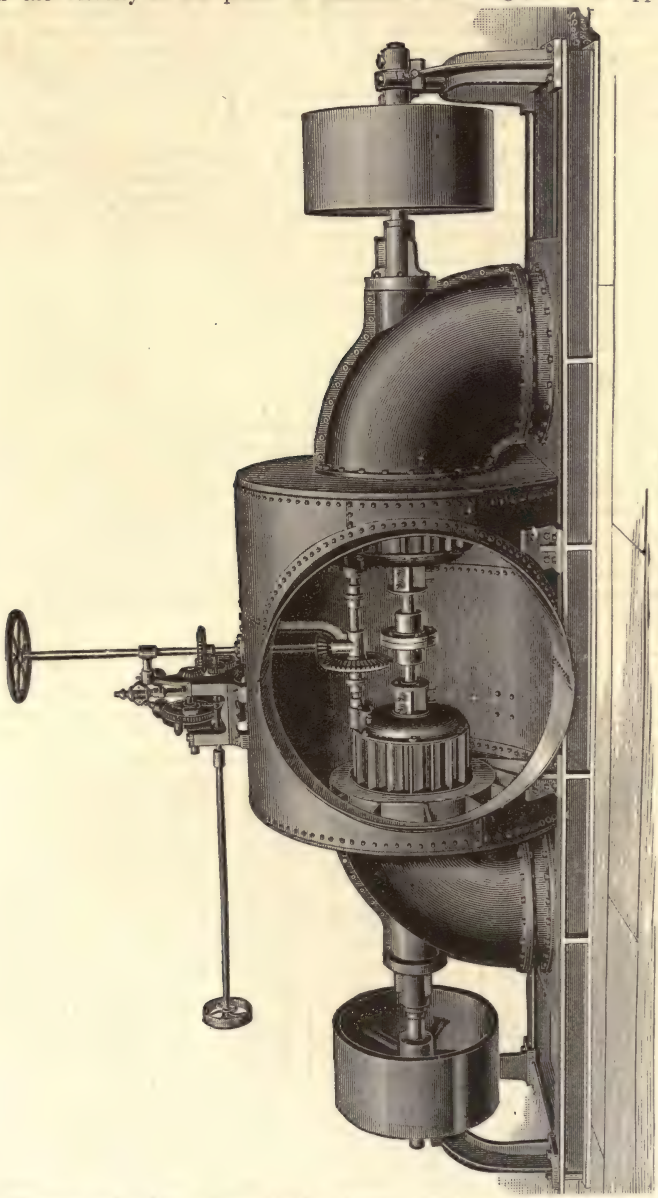


Fig. 11. —Victor wheel on horizontal shaft.

been *about* 58 per cent. of the theoretical velocity. Emerson's test shows ·6345 per cent. with half-water. Fig. 11 shows the Victor wheel on a horizontal shaft.

Tests of a 15-*in. Victor Wheel, taken on jack shaft, after passing through a pair of bevel-gears, viz.: crown gear on wheel shaft,* 46 *teeth ; gear on jack shaft,* 26 *teeth ;* 10 *ft. circle of friction pulley;* 6 *ft. weir. Constant leak deducted* = 134·64 *cub. ft. per minute.*

No. test	Gateopen full.	Head in feet.	Weir in feet.	Water in cub. ft. per minute.	Horse-power, water.	Pounds in scale.	Revolutions wheel.	Revolutions shaft.	Horse-power, wheel.	Net effect.
1		18·05	0·962	960·21	32·72	150	367·	646	29·36	·8973
2		18·04	·965	966·94	32·89	160	342·5	606	29·38	·8 33
3		18·05	·970	973·59	33·19	165	330·	584	29·70	·8797
4		18·04	·972	976·94	33·20	170	315·	558	28·74	·8636
5		18·03	·971	975·26	33·21	180	286·	503	27·00	·8310

The Hercules Wheel.—This wheel in case is very similar in external appearance to the Victor, but has a cylinder gate, rising to admit the water, and the buckets are provided with interior flanges, which tend to confine the water at partial gate, and keep it from spreading to waste over the surface of the wheel. In this wheel, the buckets are cast singly. The bases of the separate buckets fit together and form the base of the wheel, and are bolted to an iron or steel ring which surrounds them. This wheel is so constructed as to give the highest efficiency at three-fourth gate, or seven-eighth water, and should be run so in practical use, leaving the other quarter gate to be opened in case of high water, when the waste can be afforded.

Numerous tests in the writer's possession show from 80 to 84 per cent. efficiency at seven-eighth water, and when it is considered that the apparent loss of 15 per cent. includes all the power required to overcome the *vis inertia* of the wheel, the step and bearing friction, and such small amount of *slip* of water as may be actually wasted, it will be seen that not much more than 85 per cent. should be expected from a wheel in practical use.

The accompanying record of tests of a 33-in. Hercules wheel, made a few years since at the Holyoke testing flume, is in some respects very valuable. It does not show quite so high a percentage of effect as some of these wheels have since done, but it shows a high average per cent. down to nearly half water, or less than half gate, with the highest results at about seven-eighth water, leaving the other 4 in. of gate, equal to 10 horse-power, to be used in case of back water, from floods in the river. It is the record of the last series of three days' successive tests, which varied but a small fraction of 1 per cent. in their results.

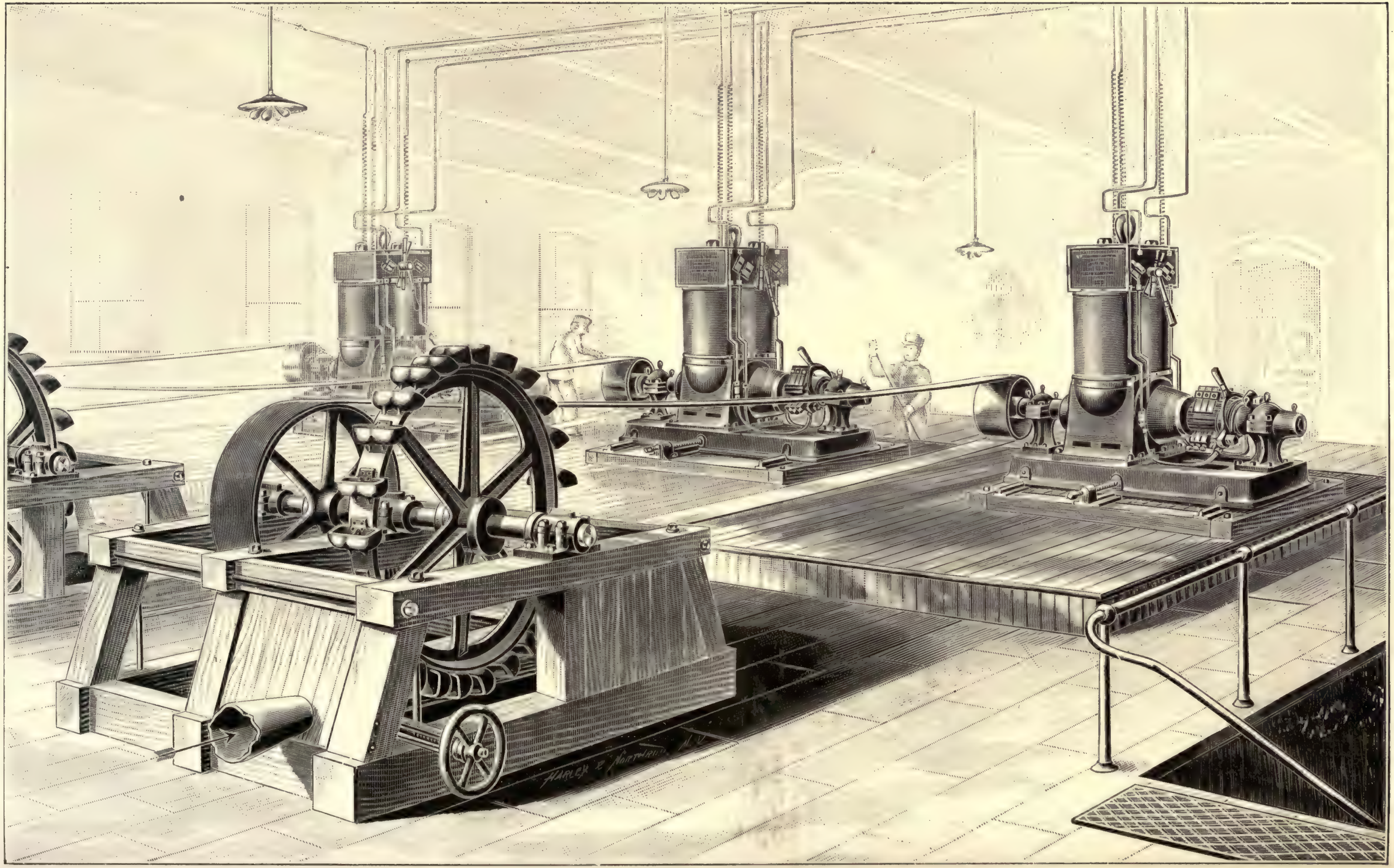
The water was measured over a 12-ft. weir, and a uniform "gate leak" of 56·23 cub. ft. per minute is in all cases deducted from the quantity of water.

The circle of the friction pulley was 20 ft., which, multiplied by the weight, and revolutions per minute, gives the horse-power. It will be seen that the highest results obtained from this wheel were at a velocity of 152 revolutions per minute. This gives a velocity of external circumference, at entrance of water, of 66 per cent. of the theoretical velocity under the head, and as the buckets are so formed as to discharge the water in as centrifugal a direction as possible, the velocity at point of maximum discharge appears, like that of the Victor, to be about 58 per cent. of theoretical. As the water enters this wheel through converging chutes, it probably reaches the wheel at a higher velocity than the 66 per cent. noted by the revolutions.

Table showing record of tests of a Hercules wheel.

No. test.	Gate opening.	Head on wheel in feet.	Head on weir in feet	Cub. ft. water per min., less waste.	Gross horse-power water.	Pounds in scale.	Revs per min., wheel.	Horse-power wheel.	Net effect per cent.
1	Full gate,	17·28	1·615	4,732·11	154·45	1,300	155·33	122·38	·7924
2	22 turns shaft.	17·26	1·610	4,710·31	153·54	1,325	152·5	122·45	·7975
3	"	"	1·615	4,732·11	154·28	1,350	149·25	122·11	·7915
4	"	"	"	"	"	"	150·5	123·14	·7982
5	"	"	1·616	4,736·48	154·42	1,375	146·5	122·08	·7906
6	Part gate. 20 turns.	17·35	1·566	4,519·69	148·14	1,300	150·	118·18	·8000
7	" " " "	"	1·565	4,515·39	148·	1,250	157·	118·94	·8036
8	" " 18 "	17·45	1·502	4,246·77	139·98	"	147·5	111·74	·7983
9	" " " "	17·42	1·494	4,213·02	138·62	1,200	154·5	112·36	·8107
10	" " " "	17·43	1·495	4,217·24	138·85	1,225	152·	112·85	·8127
11	" " 16 "	17·54	1·417	3,892·45	128·96	1,150	149·67	104·31	·8042
12	" " " "	"	1·420	3,904·79	129·94	1,125	152·5	103·98	·8000
13	" " 15 "	17·59	1·375	3,720·09	123·63	1,050	153·5	97·68	·7901
14	" " 14 "	17·58	1·330	3,539·76	117·55	"	146·	92·91	·7904
15	" " " "	17·60	1·326	3,523·8	117·15	1,000	151·	91·52	·7812
16	" " " "	17·62	1·318	3,491·95	116·22	975	154·	91·	·7830
17	" " 13 "	17·28	1·268	3,294·82	107·54	950	145·	83·48	·7763
18	" " " "	17·31	1·262	3,271·39	106·96	900	150·5	82·09	·7675
19	" " 12 "	17·25	1·210	3,070·61	100·05	850	148·	76·24	·7620
20	" " " "	"	1·206	3,055·34	99·55	825	151·	75·62	·7600
21	" " 11 "	17·40	1·153	2,855·12	93·84	750	147·5	67·10	·7157
22	" " " "	17·01	1·146	2,829·	90·89	725	151·	66·66	·7334
23	" " 10 "	17·20	1·084	2,600·84	84·50	650	153·	60·27	·7132
24	" " 9¼ "	17·34	1·050	2,478·28	81·17	600	153·5	55·82	·6877
25	" " " "	17·37	1·042	2,449·7	80·37	550	161·	53·67	·6677
26	" " 9 "	17·39	1·040	2,442·68	80·33	600	150·5	54·73	·6821

The Leffel Wheel, represented in Fig. 12, is of the horizontal-shaft type, and embodies the latest improvements in the double-discharge construction. The water is divided equally at the center, and passes laterally and parallel with the shaft in opposite directions, discharging downwards on each side of the wheel through curved pipes. This casing is made as narrow through the central portion as possible, for the purpose of obtaining the shortest distance between the journals, bringing them as near to the wheel as the discharge space will admit. These wheels may be used for various purposes, particularly where a large amount of power is transmitted from a main horizontal line of shafting, and from the pulleys of which direct connection can be made to one or more pulleys on the horizontal water-wheel shaft. Many applications of double-discharge wheels have been made to electric lighting, electric power, and other uses, directly from pulleys on the water-wheel shaft to the pulleys on the dynamo, the saw arbor, or the pumping machinery.



DRIVING DYNAMOS BY THE PELTON WATER-WHEEL.

A novel form of the Leffel wheel is known as the twin combination. This consists of two regularly built James Leffel wheels, either standard or special, placed within a large cylindrical wrought-iron casing, with cast-iron heads, the whole affair being substantially and durably built. Both wheels discharge the water toward each other, which unites and passes

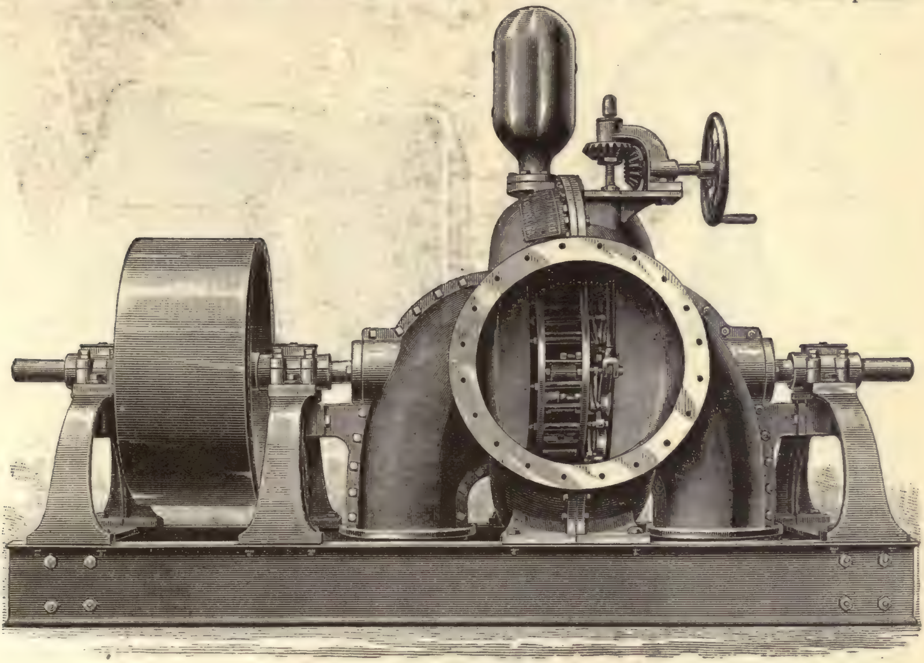


Fig. 12.—Leffel wheel.

downward through a single central draft tube of large capacity. The changes in general design of the standard Leffel wheel which have been made of late years, consist in wider gates and correspondingly wider buckets. This arrangement secures a greatly enlarged capacity for water, and consequently a largely increased power for the same size of wheel; affording a concentration of power in a smaller space.

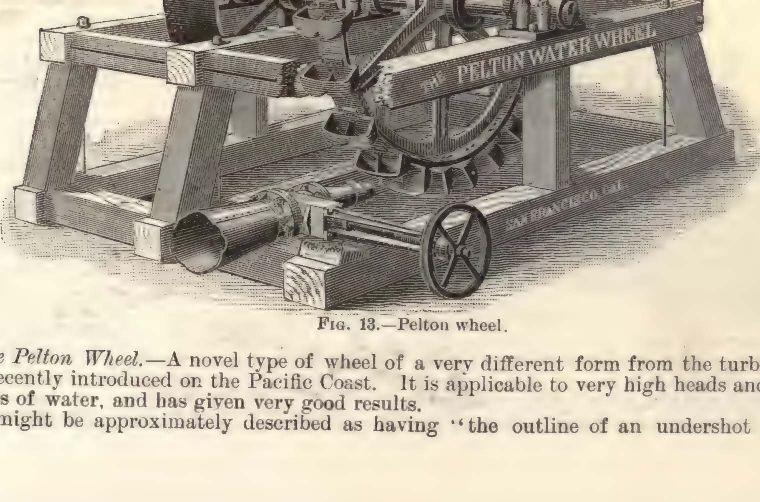


Fig. 13.—Pelton wheel.

The Pelton Wheel.—A novel type of wheel of a very different form from the turbine has been recently introduced on the Pacific Coast. It is applicable to very high heads and small streams of water, and has given very good results.

It might be approximately described as having "the outline of an undershot wheel,

with the buckets of a turbine." Its general construction will be readily understood from Fig. 13. The important feature is the peculiar construction of the bucket, which is illustrated in section, Fig 14, and in perspective, Fig. 15. The bucket is in form of a paraboloid, and has a central wedge which splits the entering jet of water. This jet then passes to the

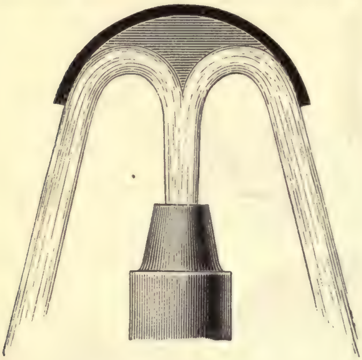


FIG. 14.—The Pelton bucket.

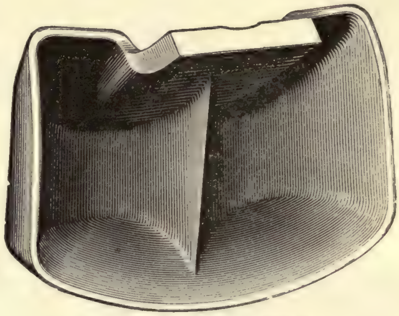


FIG. 15.—The Pelton bucket.

right and left, following the curve of the bucket, and is discharged at its periphery, having imparted all its energy and motion to the wheel, and falling away as dead water. Mr. Ross E. Browne, hydraulic engineer of San Francisco, who has tested this wheel, reports an efficiency of 82·6 per cent. under 50-ft. head, with a 15-in. wheel, and says that the velocity of the bucket should be one-half that of the jet. Other tests of a 6-ft. wheel, by Messrs. Edward Coleman and George Fletcher, in 1884, showed an efficiency of 87 per cent. In this case the velocity of bucket as compared to the theoretical velocity of jet was about 52 per cent.

The great simplicity and economy of construction of this wheel commends it to attention, and it is especially available for *very high* heads and very small volumes of water. In the last test quoted, the head of water was 380 ft., the diameter of pipe, 22 in., and the diameter of nozzle through which it was delivered was 1·89 in. The power obtained is stated as 107 horse-power, and the revolutions of wheel per minute, 255½. The water used is stated as 2·819 cub. ft. per second, or 169·14 cub. ft. per minute.

Now, the Leffel 6½-in. wheel, one of the smallest turbine wheels in use, would use this amount of water under 100 ft. head, give 27·3 horse-power, and make 2,080 revolutions per minute. This shows the advantage of this wheel in reducing the number of revolutions to a more practical point, by the use of very small buckets on a wheel of large diameter. Were a turbine to be especially constructed for such a head, a 12-in. wheel, having a diameter of 8 in. at central point of discharge, would require to make 2,900 revolutions per minute to bring its velocity of discharge to that of the "*vena contracta*" under 380 ft., although a turbine of larger diameter, with small apertures, might undoubtedly be designed for the purpose, like Mr. Foumeyron's celebrated turbine of St Blaise.

The Pelton wheel has proved especially efficient in the electrical transmission of power, and, as is illustrated in Fig. 16, may be placed directly on the dynamo shaft. The full-page illustration represents an electric lighting station in which all the dynamos are driven by these wheels. As examples of the use of the wheel for driving dynamos, the following may be noted: The power station of the American River Syndicate is located at Rock Creek, Eldorado County, Cal. The plant consists of an 8-ft. Pelton wheel, which, running under a head of 110 ft. at 100 revolutions with a 5½-in. nozzle, has a maximum capacity of 130 horse-power. To this wheel is connected a 100 horse-power Brush generator, speeded at 900 revolutions, the current from

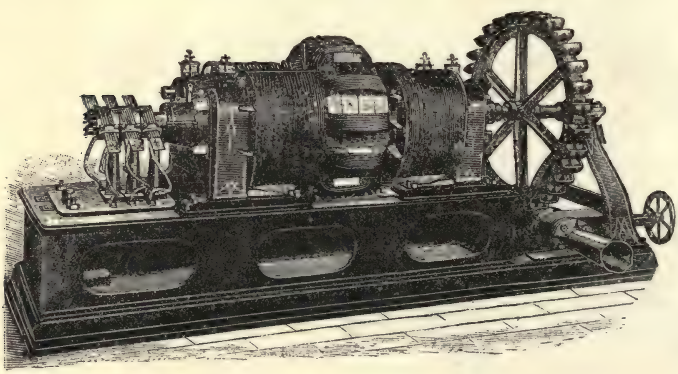


FIG. 16.—Direct driving of dynamo by Pelton wheel.

which is carried to the mill through a single insulated copper wire, No. 3 B. & S. gauge, the return being made by a wire of the same size, making a four-mile circuit. The power from the generator is communicated to the countershaft of the mill by a 70 horse-power Brush motor running at 950 revolutions. The machinery operated consists of three centrifugal roller mills, a ten-stamp battery, and a rock breaker. The Pelton wheel under these conditions shows an efficiency of 86 per cent., while about 75 per cent. of the power thus generated is available for duty at the mill. Sufficient power is taken from the main circuit to run sixty incandescent lamps for lighting the entire works.

It only remains to be said that the modern turbine has been brought to such a point of perfection that, with proper attention to correct velocity of discharge and ample water passages, from 80 to 85 per cent. of the gross power of the water can be safely estimated as secured by 8 or 10 of the most popular types of wheel.

Way, Balancing : see Balancing Way.

WELDING, ELECTRIC. One of the oldest known facts in the working of iron is that portions, when softened or rendered plastic by heat, could, under suitable conditions, unite or weld together. Owing to this property, the earliest iron smelters were able to secure pieces of moderate size from the granules obtained in the reduction of the ores in their crude furnace operations. These were carried on on too small a scale to give rise to iron which had in it a portion of carbon conferring fusibility, or cast-iron. In general, softened materials, such as warm wax, pitch, or heated glass, possess the property of welding in an eminent degree. This is probably due to the existence of a comparative freedom of movement of the molecules of materials in a plastic condition, which allows the cohesive force to be exerted between particles or surfaces brought very near together, or into complete contact one with the other. For such operations of welding, the surfaces must be clean and free from interposed scale or dirt, or the conditions must be such that these latter are expelled from the joint during the operation. With platinum or glass in the heated or softened state, the union takes place with great facility, owing to the non-oxidability of the surfaces in contact, but in the case of such a metal as iron, which forms a scale of black oxide when heated in the air, the temperature for welding must either be so high that the oxide is liquefied and so made to exude from the joint or surfaces brought together ; or, for the same exudation or auto-cleansing to take place, a flux which dissolves and renders liquid such scale or oxide at a lower temperature is required. In still another way—namely, by extrusion of sufficient of the metal itself outwardly from the joining surfaces—the condition of absence of scale or oxide at the joint may be secured. The application of the heating effects of electrical currents, together with mechanical manipulation, marks a recent advance in the art of welding metals. The well-known ease with which electrical currents may be regulated or governed in their effects, contributes greatly to the success of the operation.

The principles of the Thomson process of electric welding, which principles are, with some modifications, applied to the operations of electric forging and shaping, upsetting, riveting, etc., may be briefly stated as follows : The pieces to be operated upon are held in suitable clamps or supports, and provision made for the passage of heavy currents of electricity at very low pressures or potentials through the joint or from piece to piece. The current usually enters by the holding-clamps, though sometimes other means than the clamps are used to pass current into the pieces. Indeed, in some cases no clamps are used, but merely contact surfaces bearing on the work-pieces at or near the joint. Various modifications are made in the devices employed so as to suit the character of the work itself. The result of passing a heavy current through the metal of the joint is a localization of the heating effect of the currents to the joint itself, or, more correctly, to the metal at the joint and at a small distance each side of it. During the passage of current, the pieces are pressed together in firm contact, and since there is no arc, the heating occurs by the resistance of the solid metal, and not by that of any air or gas in a space between them. Neither does the heating altogether depend on the fact that the meeting portions do not fit perfectly, such imperfect fit giving increased resistance at the joint, for a solid bar joining the clamps would be heated between such clamps, though its resistance is not increased by the existence of any break or partial fit of surfaces in contact. The heat developed in any portion of an electric circuit depends upon the resistance which it offers to the current and upon the amount of current passing. It is also in proportion to the square of the strength of that current.

If the resistance be great, a small current will be required, but the pressure of the current will need to be high enough to force the current to pass, according to Ohm's law,

$$\text{Current} = \frac{\text{E. M. F. or pressure}}{\text{Resistance}}.$$

But if the resistance in the circuit be low, the current, to effect heating, will require to be increased, while the pressure, or electro-motive force, will be less. It is of course evident that in the case of two bars or pieces of metal held together firmly, and arranged so that a current when passed will only go through the pieces at the meeting portions, and a little of the metal each side thereof, a very low resistance will exist in the path of the current through the pieces. Hence the desired heating for welding will demand that the current strength or rate of flow of electricity be very high. This current, with bars of copper up to 1 in. or a little more in diameter, or with bars of iron of seven or eight square inches of section at the weld, may reach thirty or forty thousand amperes, yet the pressure or potential difference causing such flow may be no more than two volts. In actual practice in electric welding, the strength of current and pressure depend on the conditions of the work, the desired rate of heat development, and other factors. It therefore varies greatly. For obtaining

the large currents at the low pressure indicated above, the development of the art has shown that storage cells or accumulators may be used, that dynamo-electric machines may be constructed to furnish the currents, or that currents of comparatively high pressure and small flow may be transformed or exchanged by induction apparatus for currents of very low pressure and great volume. The latter method is the one adopted in almost all of the apparatus constructed for practical use in electric welding. It enables the dynamo, which is usually made to furnish alternating currents of about 300 volts pressure, to be placed where it is convenient to drive it by power, while the working apparatus or welding transformer may be elsewhere located, two wires of moderate section being used to convey the current from the dynamo to the transformer. The dynamo may be of such size as to be able to supply current at the same time to several welding transformers, or welders, as they are called, and located in different parts of a manufacturing establishment.

The general character of the apparatus may readily be seen by an examination of Fig. 1, which represents the second machine made, and which machine has become historic.

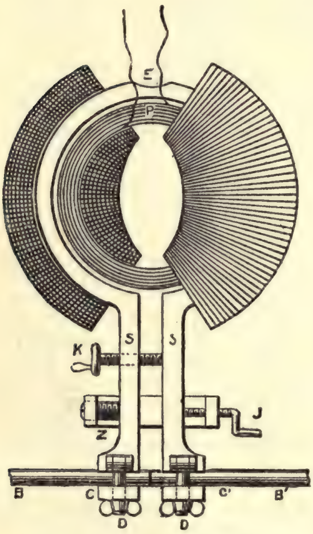


FIG. 1.—Electric welding machine.

The primary, *P*, Fig. 1, is a large, open ring, and is composed of many turns of insulated copper wire. The secondary, *S S*, is simply a single heavy bar of copper bent to make only one turn outside the primary coil; its ends are turned outward, and provided with powerful screw clamps, *C C′*, for holding the pieces, *B B′*, in place and in abutment. The form of the secondary is somewhat like a Jew's-harp, with the clamps on the ends of the parallel portion. The bar, *S*, is thinned at *E*, and broadened there so as to give a certain flexibility. A powerful screw and spring at *Z J* forces the clamps together when the apparatus is used. Over both primary and secondary a heavy sheathing of iron wire is wound, forming virtually an endless magnetic circuit of iron around them. The iron wire is wound upon a casing which encloses the two coils, *P* and *S*, and prevents the iron wire from interfering with the free movement of the parts of the bar, *S*, and the clamps, *C C′*. The resistance of the secondary bar is about .00003 ohm. Vigorous alternating currents, of comparatively high potential, passing in the primary circuit, *P*, generate in the bar, *S*, when its circuit is closed by pieces, *B B′*, to be welded, a low electro-motive force acting over a circuit of very low resistance, and giving rise therein to currents of enormous volume. To prepare the pieces for the operation of welding by electric means, all that is necessary to be done is to clean those parts of the pieces which enter the clamps by filing or emery, and to see that the ends or surfaces to be welded are clean enough to effect a contact when pressed together after placing in the clamps. The shape of the abutted ends matters little, as a joint will be formed even when the ends are irregular, but it is better to have the surfaces either flat or with the edge chamfered a little, or with one or both surfaces made somewhat convex, in order that the joint may begin in the middle of the abutted section. The pieces are placed in the clamps, with the ends to be joined projecting therefrom a small amount, and a moderate pressure tending to hold them in abutment, is applied. Sometimes at this stage a flux, as borax, is added, after which the current is put on. Heating of the abutted ends at once begins and proceeds with a rapidity depending on the current flow, and the size and nature of the pieces treated, reaching the welding heat or temperature of union for the metal, or even reaching the point of actual fusion. With great energy of current, joints on iron bars of over $\frac{1}{2}$ in. diameter have been made in less than three seconds after applying the current, and with small wires the action is almost instantaneous. The scale on which the apparatus is constructed depends, of course, on the character and dimensions of the pieces to be treated or worked. Wires of $\frac{1}{50}$ of an inch in diameter up to bars of several inches in diameter may be welded by suitable sizes of welders. The current strength required in such case depends on the nature of the metal or alloy as regards fusibility, specific heat, resistance, etc. Easily fused metals, like tin or lead, require less current, because the temperature of welding is just short of their fusing points, which are, of course, comparatively low, while their higher specific resistance to the flow of current, as compared with iron or copper, still further lessens the current required to produce the heat in any given section.

The metals silver and copper, which, in their pure state, are the most perfect electrical conductors known, and which at the same time possess a very high heat-conducting power, require for electric welding currents of relatively much greater amount than do iron, platinum, gold, etc. The conductivity for heat tends to cause a rapid transfer of heat from the joint to the clamps during the operation, which loss of power is largely kept down by making the weld in as short a time as possible. The conducted heat, as well as the heat developed by the current in passing from the clamps or current-applying contacts to the work-piece to be welded, tends to raise the temperature of the clamps or contacts, and so in a measure lessen their efficiency for conveying current, and also to injure them by oxidation. These parts of the apparatus being usually of copper, or alloys rich in copper, are, however,

in the actual machines kept cool by a circulation of water, and are in this way preserved from deterioration. To this end they are on the larger machines constructed with water passages which are connected to a water supply. In such machines also it is not unusual for hydraulic force or hydraulic cylinders to be provided for forcing the pieces together during welding, and sometimes also for holding the pieces in the clamps. The ease and quickness of action and perfection of control by simple valves renders hydraulic pressure peculiarly well adapted to impart the movement necessary for clamping, unclamping, pressing together in welding, etc., during the operation. In like manner the current applied in doing the work is controllable and regulable by simple switches and regulating appliances, so that the heating effects can be nicely adjusted to the size and character of the work. To such an extent is this true that electric welding machines are constructed which are automatic in character, or in which the conditions for successful welding, including the amount of current, pressure to be exerted, and point of cutting off of current, having been once determined for the sizes of work for which the machine is adapted, such work may be indefinitely repeated, since the placing of the pieces in the clamps is in accordance with set gauges on the welder. The application of current is after a certain interval followed by its automatic cutting off, and the pressure exerted to close or effect the weld is automatically applied by springs or by a definite hydraulic force. The tendency in the development of the welding apparatus is to have its action automatic even in the case of large work, at least in so far as the application of a certain amount of pressure in forcing the pieces together is concerned. In some cases the automatic character of the apparatus is more complete. This is the case in machines which automatically feed the pieces into place in the clamps, clamp or hold them, automatically apply the proper pressure and current, allow the proper amount of yield to take place in forming the weld, and automatically cut off the current, followed by the automatic release of the clamps and discharge of the pieces.

Concerning the form of the pieces which can be dealt with in the electric welder, there are but few limitations. Of course, the welding of uniform sections of wires or bars presents the least difficulty. These sections may be round, square, polygonal, or irregular, provided the holding clamps are adapted to grasp them and hold them securely. Flat strips like band saws may be operated upon similarly, and even teeth may be welded into saws where they have been broken out. The edges of sheets of considerable width may likewise be united. The welding of pipe sections of large or small diameter is performed with facility. In such work, as also is the case of solid-bar welding, in many instances, the weld is perfected by hammering, the blows of a light hammer, rapidly delivered at the weld while the metal is heated, being preferred. For such purposes, both mechanical and rapid pneumatic hammers which can readily be applied to the work are in use. Pipe welding in the lighter work may require a mandrel introduced into the interior of the pipe, during the hammering, though this is not a necessity in the case of pipe with heavy walls. The process finds application in the welding of iron pipe sections into continuous long lengths for coiling. It is readily applied to the joining of lead-pipe sections without solder, and without any enlargement at the joint. The diameter and thickness of the pipe is preserved, while the metal becomes a continuous piece. When applied to the welding of tires or rings, the conditions are such that it might be expected at first that the electric current, if applied by contacts or clamps at each side of a break or proposed joint in a ring, would be liable to short-circuit itself through the complete portion. Some current does pass around such a ring, but it is slight as compared with that which passes at the proposed weld or joint. This is owing to the greater resistance to the current given by the length of metal in the path formed by the metal of the ring outside the clamps, as compared with the short length between the closely approximated clamps where the joint is to be made. Moreover, with alternating currents the path around the ring has a much higher self-induction, which acts as an opposing influence, and so acts to check current in that path. Further, if desired, the insertion of a magnetizable body of iron in the interior of the ring, such body being made of a bundle of iron wires or plates, will give an opposing effect, or self-induction so greatly increased that in most cases very little current will pass around the ring as compared with that which passes at the joint, and which heats and welds the same. It will be evident, without further explanation, that pieces of special or irregular outline may be operated upon or welded to others by simply providing the necessary and suitable clamps and contacts for passing into the pieces the proper current, and for pressing the metal together at the joint, provided, of course, that the requisite projection of parts and meeting of pieces between the clamps is permitted.

While in most cases the operation of electric welding by the Thomson process is effected by butt welding, or joining the pieces in a plane substantially transverse to the line joining the pieces, it is equally applicable to making lap welds ; but practically the butt welds made electrically are equal to lap welds as ordinarily made, and often supplant the latter with great advantage. It is customary to dress off or hammer down the burr or expansion left in the butt welding of the pieces, due to their being pressed together while in a plastic state, but in many cases the presence of the burr is not objectionable, while it is considerably conducive to strength, as it makes the weld in most cases the strongest part of the structure. In other cases the burr may, by suitable dies, be finished into a uniform bead which is ornamental in character. (See Fig. 2.) In regard to the preparation which is given to the ends of the pieces before welding, it is noticeable that for moderate-sized wires the ends may be simply cut off in wire cutters, and abutted thereafter for passage of current and welding. In larger work, such as large bars of iron, the ends are somewhat rounded

or convex, and the heating and welding therefore begins in the center, or near the axis of the bar. As the metal heats, softens, and yields, the weld continues to spread laterally until it includes the whole of the section. It has been proved possible to weld bars without producing any expansion or burr at the joint by first preparing the ends suitably—*i.e.*, by first removing from the ends of the pieces just that portion of metal which during the welding would have gone to form the expansion. However, this operation requires skill and judgment, and is not generally practised. The degree of heat to which a bar may be brought in the electric welder is only limited by the fusing point of the metal, unless the losses by conduction and radiation from pieces too large for the machine, limit it. The fact that most metals when heated possess less conductivity for current is important, for it lessens the volume or flow of current required to be passed. Otherwise the current would need to be increased as the section welded was increased during the operation. This, however, is not requisite, for in the case of iron, as an example, the specific resistance of the metal at the welding heat may be ten to twelve times what it is at ordinary temperatures. This fact has also another important bearing on the operation of electric welding, for it leads to a uniform distribution of the heating effect in the different parts of the weld, assuming that no disturbing effect which otherwise prevents such uniformity exists. The action is briefly that if in a weld one portion of the meeting surfaces is comparatively cooler than another, its resistance will be less, more current will therefore be diverted to such cooler portions, and a consequent increased heat production will ensue thereat which rapidly brings the metal to a temperature nearly uniform with the rest.

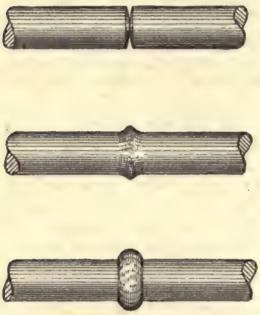


FIG. 2.—Butt welding.

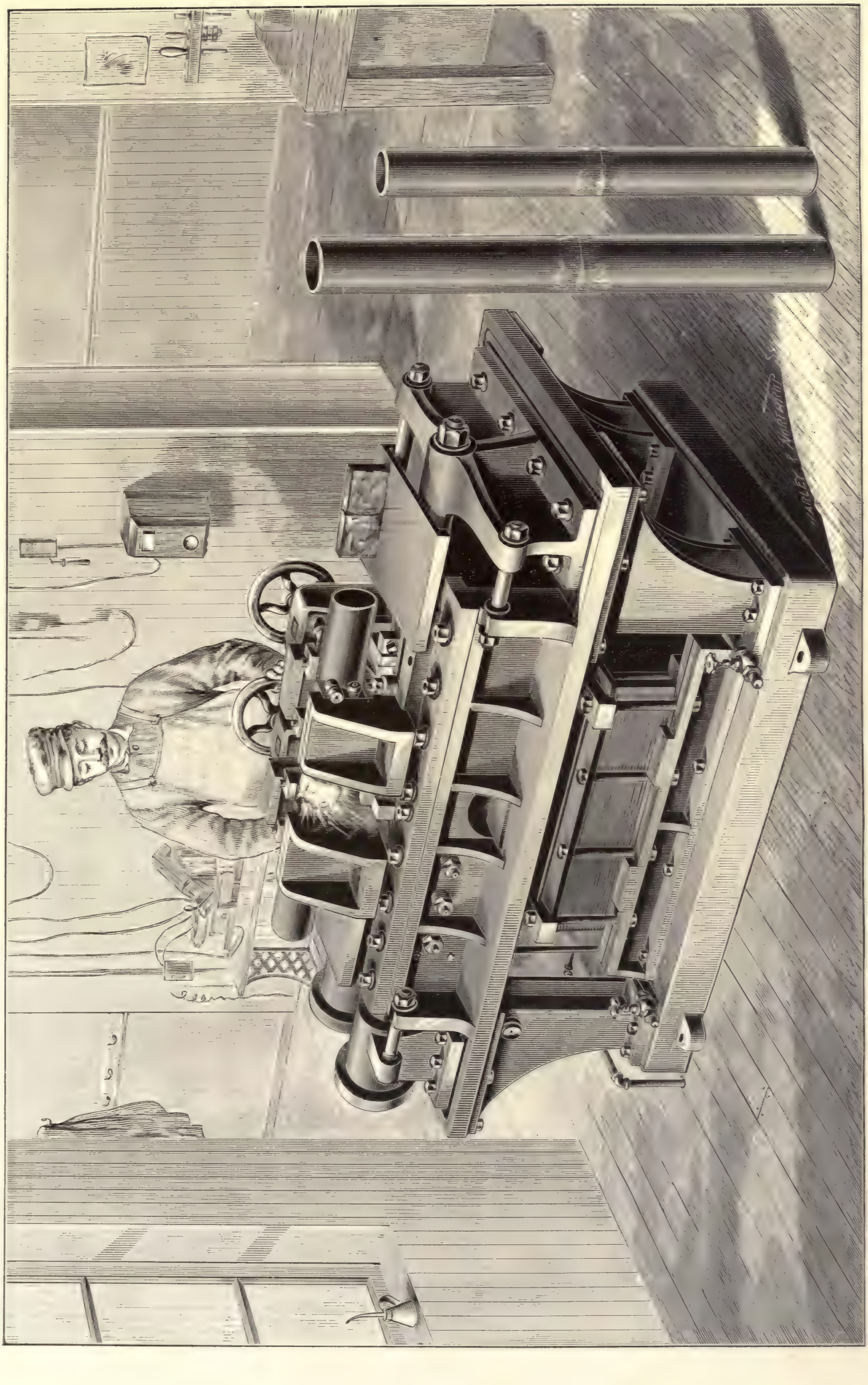
The development of the Thomson electric-welding process has shown that instead of a few only of the metals and alloys being the weldable ones, there are few if any exceptions among the metals so far as their weldability by electricity is concerned. It has appeared also that in many cases metals are united with great ease which before were regarded as non-weldable. Doubtless the reason for this is that the perfect control of temperature and pressure obtained enables the operator to work within so much narrower limits of fusibility and plasticity as would be impossible with the ordinary methods. The metals which have been found to weld with facility include wrought-iron, cast-iron, steels of various grades, steel castings, Bessemer metal, copper, lead, tin, zinc, nickel, cobalt, silver, gold, platinum, antimony, bismuth, magnesium, aluminum, manganese, cadmium, and such alloys as cast and rolled brass, bronze, gun metal, aluminum brass, aluminum bronze, phosphor bronze, silicon bronze, coin silver, gold of varying fineness, type metal, pot metal, pewter, solder, German silver, fuse alloy, aluminum iron, etc. The process permits the combination of different metals and alloys to be effected without solder, such as copper to brass, copper to soft iron, copper to German silver, copper to gold, copper to silver, brass to soft iron, brass to cast-iron, tin to zinc, tin to brass, brass to German silver, brass to tin, brass to mild steel, wrought to cast-iron, wrought-iron to cast-steel and to mild steel, gold to German silver, gold to silver, gold to platinum, silver to platinum, soft iron to cast brass, iron to German silver, iron to nickel, tin to lead, etc.

The joining is frequently effected without the use of a flux, though in some cases a flux, such as glass of borax, is found to assist the operation. The energy required to effect a weld is of course different with the different metals, according to conductivity for heat and electricity, fusibility, section, shape of pieces, and other factors.

The following table shows some of the results obtained in welding iron, etc., and with the time occupied in the work.

Energy absorbed in Electric Welding. Professor Thomson's process.

IRON AND STEEL.					BRASS.					COPPER.				
Area in sq. in.	Watts in primary of welders.	Time in seconds.	Horse-power applied to dynamos.	Foot lbs., unit 1,000.	Area in sq. in.	Watts in primary of welders.	Time in seconds.	Horse-power applied to dynamos.	Foot lbs., unit 1,000.	Area in sq. in.	Watts in primary of welders.	Time in seconds.	Horse-power applied to dynamos.	Foot lbs., unit 1,000.
0·5	8,550	33	14·4	260	·25	7.500	17	12·6	117	·125	6,000	8	10·	44
1·	16,700	45	28·0	692	·5	13,500	22	22·6	281	·25	14.000	11	23·4	142
1·5	23,500	55	39·4	1,191	·75	19,000	29	31·8	508	·375	19,000	13	31·8	227
2·	29,000	65	48·6	1,738	1·	25,000	33	42·0	760	·5	25,000	16	42·	369
2·5	34,000	70	57·0	2,194	1·25	31,000	38	52·0	1,087	·625	31,000	18	51·9	513
3·	39,000	78	65·4	2,804	1·5	36,000	42	60·3	1,390	·75	36,500	21	61·2	706
3·5	44,000	85	73·7	3,447	1·75	40,000	45	67·0	1,659	·875	43.000	22	72·2	872
4·	50,000	90	83·8	4,148	2·	44,000	48	73·7	1,947	1·	49,000	23	82·1	1,039



It will be seen that the foot pounds of energy for a given section of copper are about half as much again as with the same section of iron, and that the figures for iron and brass are not very different. The high heat conductivity of copper, in consequence of which more of the length of bar is heated, or more heat conducted away from the joint, doubtless accounts for the difference noted. It may also be remarked that the energy required increases more rapidly than the section, and in a certain proportion, which is doubtless due to the fact that in the larger pieces, though less subject to radiation of heat during the welding than smaller pieces, there is required a longer time for the welding, and consequently an increased conduction of heat from the joint results. If the time of welding were made the same for varying sections, it would appear that the energy used would be more nearly in proportion to the section. The end pressure in forcing the pieces together should, for the best work, be carefully kept, as, if a proper amount be applied, the welding will be at once effected on the metal pieces arriving at a certain degree of plasticity, the quickness or slowness of the heating simply governing the time which will be consumed in heating to that plasticity. The pressure to be applied in effecting butt welds electrically varies with the material and section of the pieces at the weld. It is with steel about 1,800 lbs. per sq. in.; with wrought-iron, about 1,200 lbs.; and for copper, about 600 lbs. per sq. in.

In the industrial application of the process the source of current has usually been a special dynamo, constructed to deliver alternating currents at about 300 volts, and of a periodicity of about 50, or 100 alternations per second. Where but a single welder has been employed it has been customary to regulate the welding currents by varying the field-exciting current by a resistance or other device. Fig. 3 shows a plan of the connections used in such a case. Fig. 4 also shows the arrangement of a composite-field self-exciting dynamo, which is controlled by a variable reactive coil alongside the welder, altering the self-induction in an armature branch or circuit, which in turn causes a variation in the field current of the dynamo.

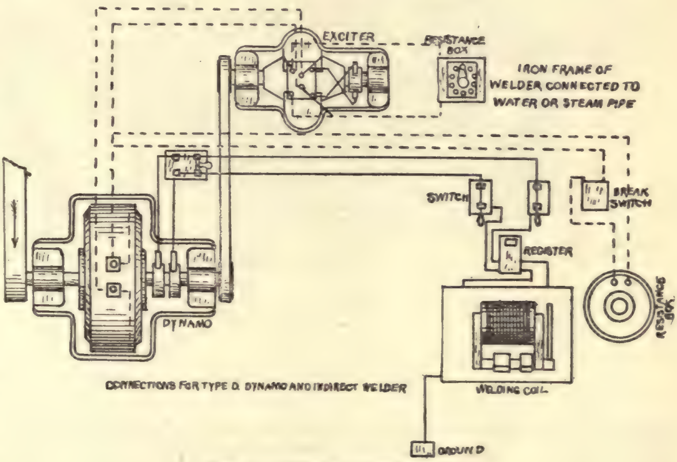


FIG. 3.—Indirect electric welder.

In other cases in which quick work is to be done, the conditions at the dynamo are set once for all, and the mere closing of a switch effects the weld, and the current is self-regulating. In this case the dynamo is greatly over-compounded, or increases its electro-motive force rapidly with an increase of resistance, or counter force, in its circuit, due to heating of the pieces during welding. In the case of several welders fed from the same dynamo as a source of primary currents, such methods are inadvisable, and are replaced by constructions which yield constant potentials, or the dynamos are self-regulating in the same sense as dynamos used in electric lighting are.

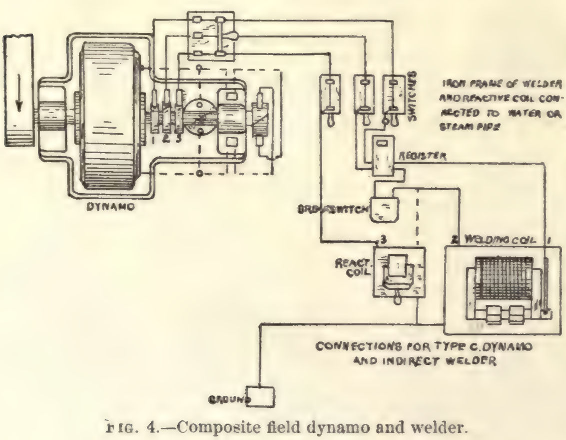


FIG. 4.—Composite field dynamo and welder.

The actual construction used in the welders themselves undergoes great variation, according to the size and character of the work for which they are designed. The direction and nature of movement to be given to the clamps in effecting the weld will of course govern the construction of the welder itself to a large extent. As the electric welding machine may be regarded as a special induction coil or transformer, combined with holding and

moving clamps and pressure apparatus simply, it will also be understood that a change in the latter does not necessarily involve a change in the former. Indeed, in the type of welder called "Universal," the strong iron frame containing and supporting the transformer portion of the apparatus simply has an upper double platform, the portions of which are the

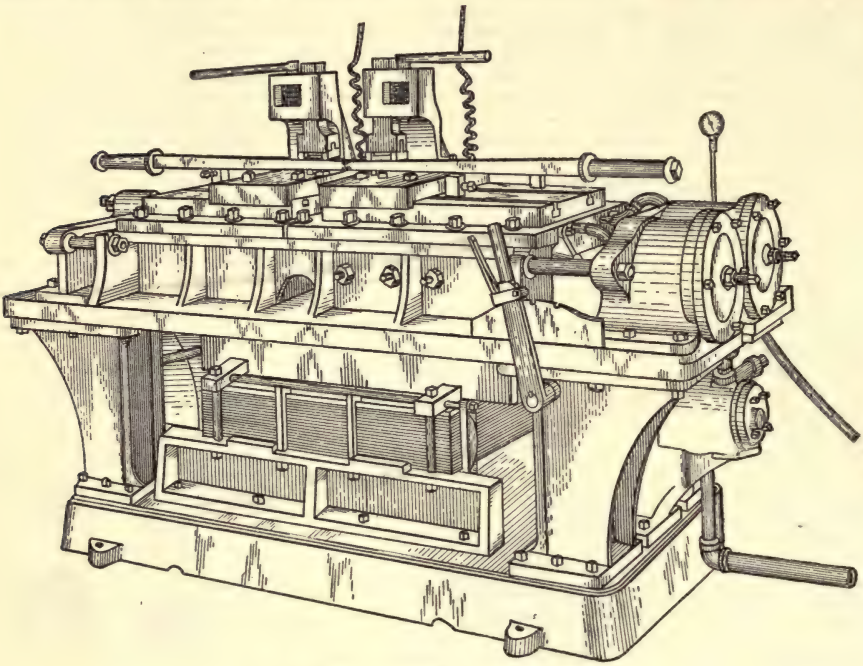


FIG. 5.—Electric welding for varying forms.

terminals of the heavy secondary conductor, insulated from each other and provided with grooves and holes for bolts similar to an iron planer bed. These permit the attachment of varying forms or arrangements of clamping devices to suit a variety of forms and sizes of welding work or metal shaping, for which the machine is adapted. Such a machine is shown in Fig. 5, bearing clamps for axle-welding bolted to its platen. Hydraulic cylinders are arranged to move back and forth one terminal of the secondary, arranged in guides, and whereby the welding pressure and movement is obtained. In these and other machines for electric welding, the primary coil of many turns, and the very heavy secondary conductor of only one turn, are constructed so as to be closely associated around a laminated iron core. Arrangements such as in Figs. 6 and 7, where P and S represent relatively the sections of primary and secondary, and I the iron magnetic circuit, are used. The secondary is cut, as in Fig. 7, at K, leaving its terminals free for conveying current to clamps which may be attached thereto. Fig. 8 shows a welder adapted for welding sections of pipe by hand-pressure, and gives a fair idea of the substantial character of work demanded in these later electrical productions. A pipe-welding machine of more elaborate type is provided with hydraulic-pressure cylinders, for forcing the pieces together. Both these pipe machines are provided with water circulation through the clamps, for keeping them cool and in working condition. A top view of a tire-welding machine is given in Fig. 9, the pipe for water circulation being clearly seen, the special clamps, the pressure lever, and the tire in place as welded in the machine. The electric welding process has given rise to special ways of doing work, and to special manufactures dependent on its conferring the ability to do work which otherwise could not be attempted. Examples of this are easily found, and the welding apparatus in such cases often takes on a special form peculiarly fitting it for the particular work. In the construc-

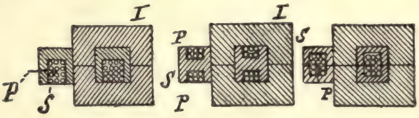


FIG. 6.—Primary coil.

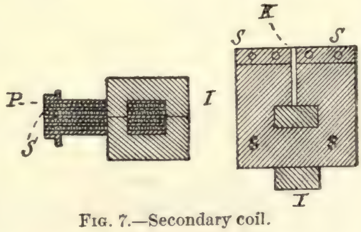


FIG. 7.—Secondary coil.

tion of metal wheels the process has been applied to unite the two parts of a hub, which,

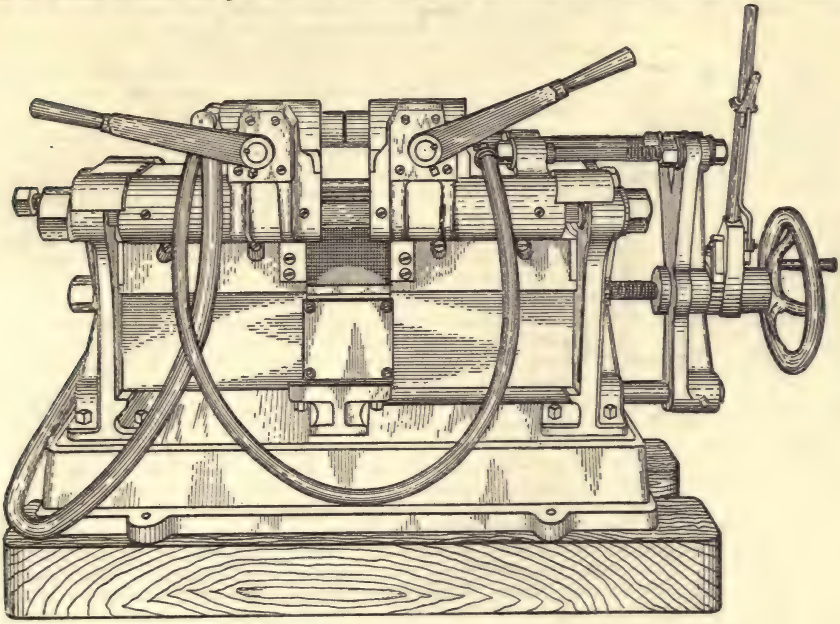


FIG. 8.—Pipe-welding machine.

when brought together and welded, serve also to clamp and weld the iron or steel spokes firmly.

Another case of the special character of the work demanding welding machines of a

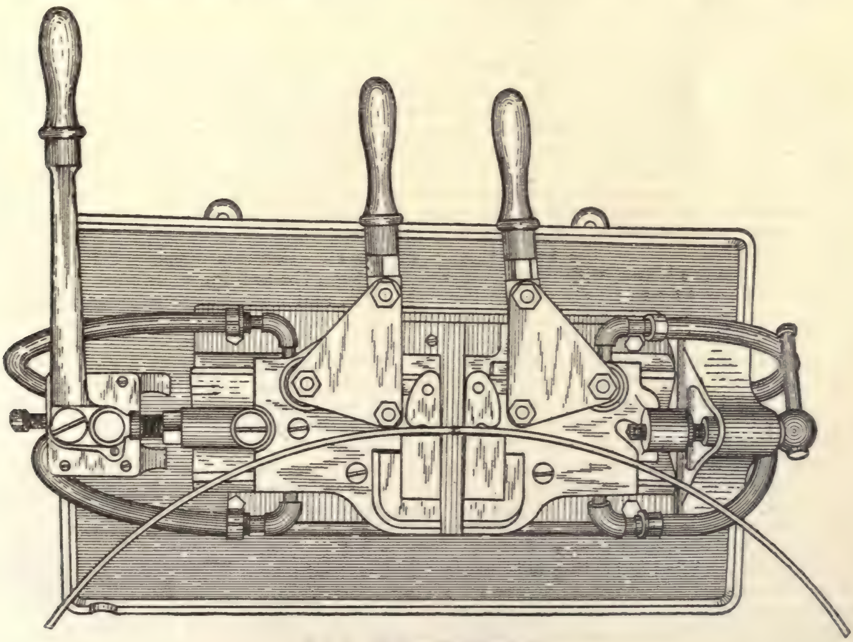


FIG. 9.—Tire-welding machine.

design and construction altogether different from other work, is in the manufacture of projectiles and shells for guns. The parts of the projectile, such as the steel point or tip, the softer tubular body, and perforated butt end, are formed separately and accurately (Fig. 10).

They are then placed in the special welder, where they are united very accurately in their axial relation, but little finishing being required to complete the work. The application of the electric welding process to wire jointing being one of the earliest and simplest cases, has become very extended, and millions of joints are annually made in wires of various size and of different metals. The joints are usually as strong as the annealed metal, or nearly so. When the wires to be united possessed a structure due to working, such as drawing through the draw plate, it is, of course, not to be expected that such structure will be retained at or quite near the joint welded electrically, as the heating anneals the wire and takes away the grain or toughness conferred by the mechanical kneading of drawing, rolling, or hammering. In such cases it is customary, where it is practicable, to hammer the joint after welding, special devices, delivering numerous quick blows of small hammers, being made for the purpose. Drawing subsequent to welding restores the structure, and the hammering is then not usually required. The application of the process to the production of chain effects a saving in weight, inasmuch as mild steel may replace wrought-iron, and, therefore, yield a chain of equal strength of less weight and cost. The uncertainty of steel welding by the ordinary process has been a bar to the use of ordinary forge welding, and electric welding, on the other hand, enables the milder steel to be employed with almost the same facility as wrought-iron. The electric process also enables bars or pieces of such shape of section as could not be worked by the ordinary welding methods, to be dealt with easily, and hence finds a wide field of application special to itself, in addition to its use for the ordinary work of bar welding, as in tires, axles, etc., pipe welding, etc. Machinery of the same general character as electric welding machines is applicable to use in electric soldering and brazing. In such cases the current is passed through one or both pieces, so as to bring them up to the temperature at which the solder melts. In the presence of a suitable flux, the operation can generally be performed with great facility and rapidity. A number of such machines have been put in operation. They possess the advantage of localizing the heat almost solely in the portions of metal at the joint, as in electric welding. In consequence, the extensive scaling of partly finished surfaces on each side of a brazed joint (such as occurs with the fire or blow-pipe often employed) is prevented, and the heating action is under the most perfect control. The clamps for holding the work may, of course, remain stationary in the case of electric soldering or brazing, though they are often made movable and adjustable for the placing of the pieces in proper relative positions prior to the heating.

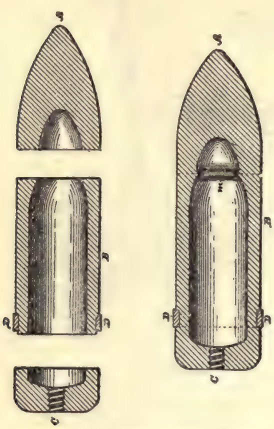


FIG. 10.—Welded projectiles.

The welding machinery is also applied with but slight modifications (generally of a purely mechanical nature) to such operations as electric forging and shaping, including upsetting and riveting. The portions of metal to be heated for such operations are included between the terminals of the heavy secondary, and are quickly brought to the proper working heat by the passage of the heavy current. After this, either by a movement imparted to the pieces clamped and heated, or by separate dies or formers, the desired shape is given to the plastic metal, and the pieces may be heated and pressed a number of times in succession, in case the nature of the work is such as to require it.

The operation of electric riveting is a form of upsetting, and is accomplished by making the rivet blank the path for the heavy secondary current. For this purpose, it is only necessary to include the blank, with or without head, between the heading tools of heavy bronze or copper, kept cool by water circulation through them, and when the blank has reached a plastic state by the current heating it, to force the tools one toward the other until the heads are sufficiently formed (Fig. 11). With sufficient energy of current the rivet body actually welds into the plates, and the plates themselves may, in part, be welded together. The heating of pieces for hot spinning or rolling may be accomplished, and the rotation of the pieces, even during the passage of current, presents no considerable difficulty. The apparatus in this case resembles a lathe, the heads of which are insulated, and then connected to the terminals of a secondary circuit of a transformer of the same construction as for welding. The tool post, or the part corresponding thereto, carries rolls or formers for manipulating the revolving hot metal, through which the current is passed for heating, and the working may proceed while the heating is in progress. The heat may also be maintained at the proper degree for giving the requisite plasticity or continuous annealing. In this way iron tubing rotated may be reduced or expanded, its ends closed, beads rolled in its sides, etc.

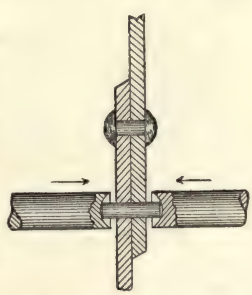


FIG. 11.—Electric riveting.

Adapting the strength of the current, or rather the heating effect of the current, to the size of the pieces in electric welding, brazing, forging, shaping, etc., is a matter easily provided for by suitable regulators. Where the pieces included in the circuit are of different sections or resistances, they will not heat

equally, unless special precautions are taken, such as proportioning the currents traversing each piece, or arranging the conduction, or cooling of the pieces during work so as to affect in greater degree the piece of higher resistance, which would, otherwise, tend to overheat. In welding, this is frequently done by giving but a relatively smaller projection from the clamps to the piece of smaller section or higher resistance.

In some instances in practical work it has been found that some saving of energy in electrical welding can be obtained by heating the pieces to a red heat before insertion into the clamps of the welding machine, which then raises the temperature to the welding heat, and only at the joint. This, for special kinds of work, may be made to save the energy required for the incipient heating during welding. Frequently, also, fuel products which are wastes of other parts of the manufacture can be employed to generate steam for electric welding, and, of course, where water-power is abundant the energy of the water may be turned into heat for the same uses.

Welding Tubes : see Pipe and Tube-making Machines.

WHEEL-MAKING MACHINES. The manufacture of wheels has received a great impulse in America by reason of the superiority of our native woods, and the severe demands made upon wheeled vehicles by our poor roads ; and in this line of manufacture our machine designers and builders have nobly met the call made upon them. There is scarcely any part of a wheel which is not now made by machinery, mostly automatic ; and among the ingenious and productive machines for making and assembling the parts may be reckoned the felly and rim sawing, rounding, planing, mortising, and polishing machines ; spoke lathes, tenoners, and throaters ; hub turning, boring, finishing, and boxing machines ; special machines for inserting and driving the spokes, trimming the ends of the tenons, driving screws into the felly, and cutting off their ends ; wheel presses, etc.

In one of the cutting-off, boring, and doweling machines made by the Bentel & Margedant Co., the spoke tenon-boring device has a hollow mandrel, which rotates, but has no reciprocating motion, and a sliding mandrel inside this, which has lengthwise motion only, so that it may be brought forward to the work without in any way interfering with the truth of the journal and bearings of the outer rotating mandrel. Where the work is brought up to the boring bed, such a precaution is not necessary.

In the Egan double spoke-throating machine, the upright column has two housings or slides, and a mandrel fitted to each slide and carrying a cutter head, which has bits of the exact shape to hollow out the part of the stock which is to come against the hub. These cutter heads are placed at a certain distance apart. The spoke is placed on a rotating table, which has pins against which the spoke rests, and which carry the stock between the cutter heads. On the outer end of the rotating table there are two cams, which causes the small end of the spoke to work up and down, giving the desired shape to the throat of the spoke.

In some machines to accomplish this purpose, the cutter heads swing from a common center ; but on this one the stock is made to adjust up and down, and the cutter-heads are stationary.

In the manufacture of fellies there is usually employed a machine having two concave or dished saws on the same mandrel, at a distance apart governed by the desired thickness of the felly ; and the material, is clamped on a sector, the radius of which is of such a length, and the centre so placed, that when the stock is swung around to the action of the two saws, there will be cut a rim having concentric inner and outer edges. Different saws are employed for fellies of different radii. It should be mentioned in this connection that the plane in which the sector bearing the stock has its vibration is not parallel with any one in which the saw arbor lies ; thus, if the saw arbor is horizontal, the sector is inclined from the horizontal to a degree corresponding to the distance above the saw center at which the stock is presented.

Rim Planer.—A machine for planing wheel rims or fellies on all four sides at one operation, either straight or bevelled, is brought out by the Bentel & Margedant Co., and calls for a very different construction from that required in ordinary planing. The requirements are that it shall plane all the four sides of a felly or of the rim, of any desired diameter and thickness, with continuous feed and without splintering or gouging the ends of the fellies or rims. It consists of a horizontal table, with a geared feed, which has such adjustment that the center line of the feed roll points to the center of gravity of any rim or felly, no matter for what diameter of wheel, gripping the felly in the true radial line of its circle, and feeding it in that line—thus, of course, lessening the friction on the guides and giving greater immunity from stoppage. There are two horizontal mandrels, the cutters on which work the two sides of the felly or rim. Their housings are on a special bed plate, on which they can be set to any required angle or bevel of the felly, in accordance with a scale placed in the bed plate. The bed plate rises and lowers in a vertical line by a crank and screw. The housings thus arranged do not require resetting for bevel or angle, but retain the given angle for wide or narrow fellies, unless a change in the bevel is desired. The table back of the lower cutter head slides on the lower bracket, and can be raised and lowered to suit the desired depth of cut. The side or vertical cutter housings are so arranged that the outside cutter head, which planes the inner side of the felly, remains fixed, while the inside one, which planes the tread, can be adjusted for thickness.

A Felly-rounding Machine made by the Bentel & Margedant Co. has for a frame a heavy column, cast with the journals all in one piece, with a wide base, the column being parted so as to give one bearing on the front and the other on the back part ; the driving

belt coming in the space between, and the mandrel pulley between the two journal boxes. The tight and loose pulleys are outside of the frame, so that the belt connection may be made from either above or below. There are two horizontal turned bars, one each side of the frame top, forming a support for a half-circle side guide, which may be adjusted thereon for wide or narrow fellies. The circular side guides may be adjusted for greater or less distance apart while the machine is in motion. The one on the back is wider than the front one, but both fit close to the circle of the cutter heads. The center guide or rest between the two cutter heads, on which the felly rests, can be raised or lowered at will during the operation of rounding. The cutter-heads are of the Denison pattern, and the head in which they are held is shown in Fig. 1.

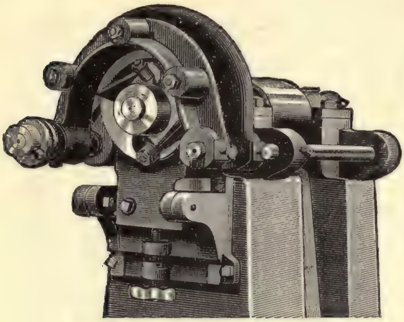


FIG. 1.—Felly-rounding machine.

The Bentel & Margedant Felly-boring Machines have an arrangement for the accurate and positive clamping of the felly, doing away with trouble on account of the irregularity of the spoke holes. The felly rests on two steel straight-edges, which afford it only two resting places, establishing the height of each hole uniformly from the face of the straight-edges, regardless of any twist or bend in the sides of the felly. A double clamp, operated by a treadle, presses the felly uniformly against the stop bars at two points on the inside of the felly, establishing thereby an accurate and uniform angle for each hole. On the left side of the treadle there is an adjusting spacer, for spacing the holes accurately after the first one is bored ; and this is set to point toward the center of the felly arc, so that the holes will be laid off accurately.

A felly-boring and screwing machine made by the same company consists in the main of a vertical column bearing a cross arm, at the short end of which there is a vertical boring mandrel having vertical feed by a balanced lever. The same cross arm bears a spindle, having a detachable screw-driver, encased by a countersunk cup for leading the screw head to the screw driver, or a milled grip cup, which takes hold of the rim of the screw at several points and drives the screw into place ; this latter method of taking hold of the screw being preferred, as it is quick in action and does away with the danger of splitting the head. Both the boring and the screwing mandrel are worked by the same lever. By raising it, the boring spindle, which runs twice as fast as the screw-driver spindle, descends and bores the hole ; then pushing the lever down, the boring spindle is raised and the screw-driver spindle lowered, driving the screw into the felly. The spindles are connected by a chain, which may be unhooked if desired. The rim of the wheel rests, during the operation, upon a small adjustable table ; the hub being held by a chuck with jaws, operated by a screw. Adjustment for wheels of different diameters and thicknesses is effected by a rod passing through the column connecting with the wheel holder, being movable in and out by a hand lever. By running wood screws into the felly where the tenon of the spoke enters, the splitting of the former is prevented.

The enormous development of special machinery may be pointed out by one, for instance, which is intended to supersede the heretofore annoying operation of cutting off that part of the screw head which remains projecting on the face of a wheel after the felly or rim screw, used by many manufacturers to bind and strengthen the rims or fellies of wheels, is driven home. In one of these machines, made by the Bentel & Margedant Co., the wheel is placed on a short upright mandrel, which is adjustable horizontally to suit different wheel diameters ; and the internal surface of the felly is presented to the action of two heavy shears, having tool-steel dies, one of which is stationary as to movement, but adjustable for taking up wear. The other shear is in exact line with an opposite or stationary shear, and has a reciprocating movement to and from it. By this action the projecting part of the screw will be cut off close to the face of the rim, when the wheel is properly set and the screw head brought between the jaws of the shears. The wheel itself rests upon an adjustable pivot, upon which it can be moved up and down, back and forward, and set at an angle, thus permitting changes for various sizes and kinds of wheel. The machine is driven by a pulley on a horizontal shaft, which by beveled wheels drives the cutting mechanism through a short vertical shaft.

The Bentel & Margedant Wheel-polishing Machine is used for producing a finish on the treads of large wagon wheels ; it sands, sizes, and polishes both sides of the wheel at one operation. The wheel holder consists of a planed base sliding on flat surfaces to and from the sanding disks, to accommodate large and small wheels ; and to this base there are pivoted upright rigid double-ribbed supports for the wheel chuck ; these supports being swung to and from the sanding disks by a treadle, for entering and withdrawing the wheel. On one side there is a centering chuck with adjusting jaws and scroll gearing. On the opposite side is a large scroll chuck, which centers from the hub, and holds and rotates the wheel while it is being sanded. Each sanding disk has its own mandrel and housing, and the latter can be set for any bevel of rim, an index scale showing the amount of bevel per foot. The disks adjust to and from each other for different rim thicknesses, and after being

set can be thrown together or drawn apart by a hand lever, to permit the finished wheel being withdrawn and another one placed in the machine. In applying the sandpaper a number of pieces cut to size are put on each disk in layers, one over the other, and held by a screw ring, without glue; and when one layer is worn out this ring is unscrewed a little, the top layer of sandpaper picked off with a pointed instrument, and a fresh one thus presented.

The Automatic Hub-turning Machine shown in Fig. 2 is specially designed for making carriage and wagon hubs up to 20 in. diameter, and 18 in. long. It receives the blocks in the rough state, roughs, turns, cups, finishes the ends, cuts the beads and shoulders for the bands, and makes the hubs of any shape or size, at one operation. The table is built in two parts. The lower half is gibbed and fitted to the frame in V-shaped ways, with adjustment horizontally in line with the mandrel, by hand wheel and screw, to center the knives with the hub block. The upper table, with roughing and finishing knives at either end, is mounted upon and gibbed to the lower table, and slides from right to left at right angles with the mandrel by turning the large hand wheel, to bring either the roughing or

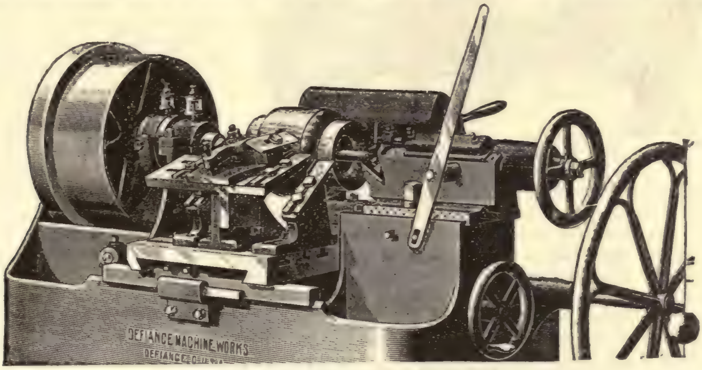


Fig. 2.—Automatic hub-turning machine.

the finishing knives to the hub block. The roughing knife, with a straight face 18 in. long, is held in a stand at the back of the sliding carriage, with its cutting edge extending downward, and when working takes off surplus material from the hub block in the form of a ribbon $\frac{1}{4}$ in. thick, the full length of the hub; the gauge governing the depth of cut or feed. The finishing knives are at the opposite end of the carriage from the rougher, with their cutting edges extending upward, consisting of a body knife with a cutting edge shaped to correspond with the style of hub to be turned; and a flat knife at either end upon the same stand, for cutting the front and back bands, with adjustment for cutting bands of different widths and diameters. The cutting-off knives, for finishing the ends of the hub, are on separate stands, below and in advance of the body and band knives. The cupping attachment is gibbed to the tail stake and provided with a gauge to regulate the depth of the cut. The shape of the knife governs the style of cup. A friction clutch turns the hub, the frictions being disengaged by a treadle.

The Automatic Hub-turning and Finishing Machine shown in Fig. 3 is for the purpose of turning plain, beaded, banded, Sarven, and Warren hubs complete, with unskilled labor. The rough hub block is placed in the machine, which first roughs it down to the proper size by a roughing knife having a straight face 12 in. long, and which is fastened to a stand at the back end of the sliding carriage, with its cutting edge extending downward, taking off a ribbon about $\frac{1}{8}$ in. thick of the full length of the hub at one cut, a gauge limiting the depth of cut. By a reverse movement of the hand wheel, the roughing portions retreat and the finishing knives come into play, the diameter to which they turn being regulated by screws attached to the carriage, so that, once adjusted, the machine turns out hubs of only one finished diameter. The finishing knives are at the opposite side of the carriage from the roughing, and their cutting edges extend upward. At each end, upon the same stand as the finishing knives, are the knives for cutting band seats; on separate stands, the knives for finishing the

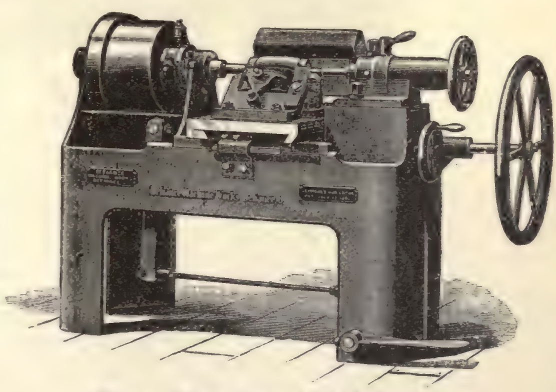


Fig. 3.—Hub-turning and finishing machine.

ends ; these last being in advance of the body and band knives. A single set of knives will turn and finish hubs of the same shape to any diameter within the machine's capacity. The feed is by friction.

The hub-boring machine shown in Fig. 4, and made by the Defiance Machine Works, is for boring hub blocks up to 12 in. diameter and 15 in long. The block may be inserted with the hard or soft part central with the boring bit, regardless of its external shape. The removal of this soft part keeps the block from checking when seasoning, and adds to the value of the product. The carriage is gibbed to the frame, and slides to and from the boring bit by turning the hand wheel 30°. The jaws which receive the hub are mounted upon the sliding carriage, the boring tool traveling through the jaws. The jaw at the back part of the machine can be adjusted to receive hubs of various lengths, and is connected with the hinge joint. The upper end is fitted with a weighted eccentric lever to open and close the jaws. In operation, the end of the boring tool should extend slightly through the hole in the first jaw, the operator centering one end of the block by the boring tool, the other end being set by the hole in the jaw at the back part of the machine ; then the weight of the lever will hold the block while being bored. The capacity is 200 blocks per hour.

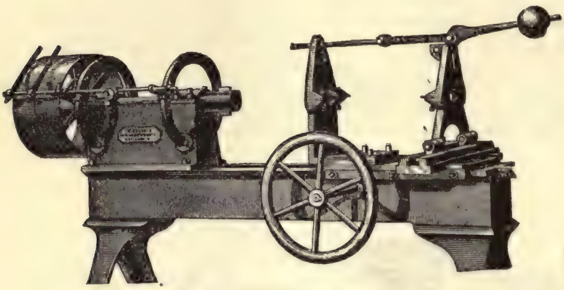


FIG. 4.—Hub-boring machine.

The Heavy Hub-boring Machine shown in Fig. 5 receives the hub block between powerful universal jaws, which hold it central with the boring tool. In boring, the soft central part of the block is removed. By the use of solid steel reamers, the hole is bored in the block complete at one operation to the proper size, and tapered to fit the hub lathe mandrel upon which the block is to be turned and finished. The hub block is placed in and removed from

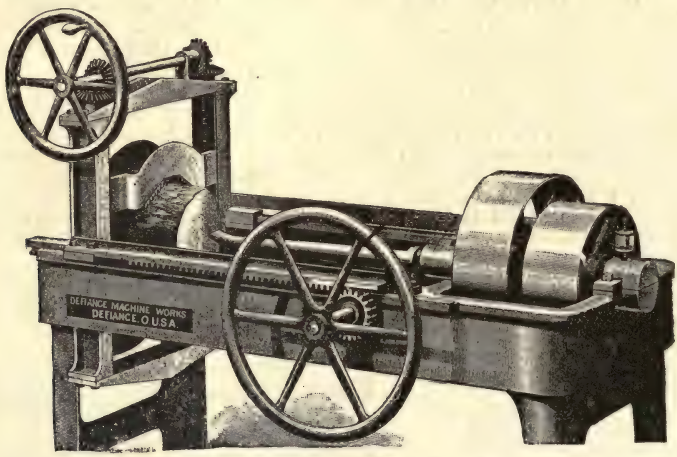


FIG. 5.—The heavy hub-boring machine.

the jaws when the carriage is moved to the back end of the machine, which is open, so that the material may be handled without lifting it over the frame. In operation the hub is clamped between the jaws, which are self-centering, and is presented to the action of the reamer by turning the large hand wheel shown.

Wheel-box Making.—In cutting the seat for the box in a wheel hub there are two principal methods—in one of which the cutter remains at rest, the wheel turning at slow speed around the advancing but not rotating cutter-head ; in the other both the wheel and the cutter-bar turn. To turn a wagon or buggy wheel at high enough speed to do free cutting is impracticable by reason of the wheel not being in accurate balance for high speed, so that it would either fly apart or fly from the wheel chuck. The method of slow turning of the wheel about a non-rotating cutter is claimed by many to tear and splinter the wood, and so disturb the fiber as to shorten the life of the hub, as the spokes and box can not be given firm support in the disarranged fiber.

The Bentel & Margedant Wheel-boxing Machine.—In this machine, Fig. 6, the wheel is turned slowly to secure perfectly true center cutting, but the cutter is also rotated at high

speed. There is a solid cast column, having a double slide, and set at a right angle to the center line of the whole machine. The bed plate resting on these slides can be moved back and forth across the machine by a large hand wheel in front, setting the whole mechanism of the cutter-bar in exact line with the center line of the wheel chuck, or within any distance of either side of this center line. The advantage arising from this adjustability of the carriage into or across the center line of the wheel chuck consists in admitting the use of cutters or reamers of the exact diameter of the hole desired, or in producing a hole of larger diameter than the cutter by moving it out of center. It also permits of enlarging or recessing the hole between the hub ends, cutting away the projecting ends of the spokes, so that they will not rest on the box, and producing offsets or shoulders in conformity with the shape of the box. For angular or tapering shapes of wheel boxes another adjustment is provided, independent of this, but which can be operated in connection therewith. It consists in arranging the lower adjustable sliding bed plate on its center with a strong circular turning slide, to which the long cutter-bar carriage is attached by compensating rotating slides, permitting the carriage to be swiveled. By this adjustment the long cutter-bar slide on which the cutter-bar housings travel can be thrown into the desired angle for cutting the sides of the box angular or beveled, to conform to the various shapes of boxes. In connection with the movement of the bed plate across the machine, this adjustment

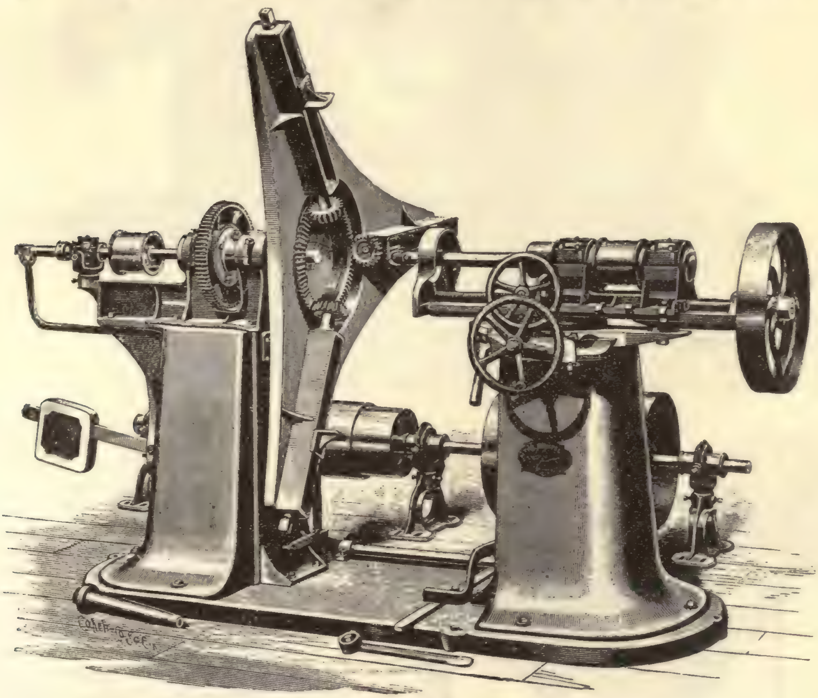


Fig. 6.—Wheel-boxing machine.

admits cutting wide, narrow, or angular sides or offsets inside the hubs. An eccentric clamp operated by a lever on the inside of the machine at the end of the radial plate, changes from straight to taper boring. The cutter-head housing is mounted on the long carriage slide by dovetailed slides, giving a movement of 20 in. back and forth for the cutter-bar and its housing. This movement is under control of the operator, and may be made fast or slow by hand or by power, at will. The feed screw passes through the whole length of the carriage, and is constantly turned by a large pulley at the end of the carriage. There is in line with the carriage, a small hand wheel having a journal and a wheel fitting closely into the threads of the feed screw, and by turning this hand wheel, the cutter may be moved to and from the hub at the speed given by the hand motion on the feed wheel, so that the cutter may enter and return from the hub at fast or slow speed at will. By grasping and holding the hand wheel at rest, not turning it either way, the automatic feed is brought into action, and the cutter-bar started forward at a uniform speed given by the large feed pulley. The framing of the machine consists of two columns on the bed plate. The column bearing the chuck for the wheel is at the back or left-hand end, the right-hand or front one carrying the boring tool. The wheel chuck consists of three well-connected heavy arms, each having a movable clamp block operated by clamp screws meeting on the common central circular rack. By applying a socket wrench to the square end of any one of the three clamp screws, the three clamp blocks may be moved together or apart, alike

and at the same time. The wheel is clamped at the rim while resting on planed plates, thus securing a true position, being guided by three points of the rim. The wheel chuck has a hollow mandrel resting in two bearings, an adjustable rotating bearing being provided in its rear, taking the weight of the chuck from its bearings. The cutter-bar for finishing the front or end of the hub passes through the hollow chuck mandrel, and has its own bearings and pulley, and movement back and forth for cutting the "crozing" of the hub. It is operated

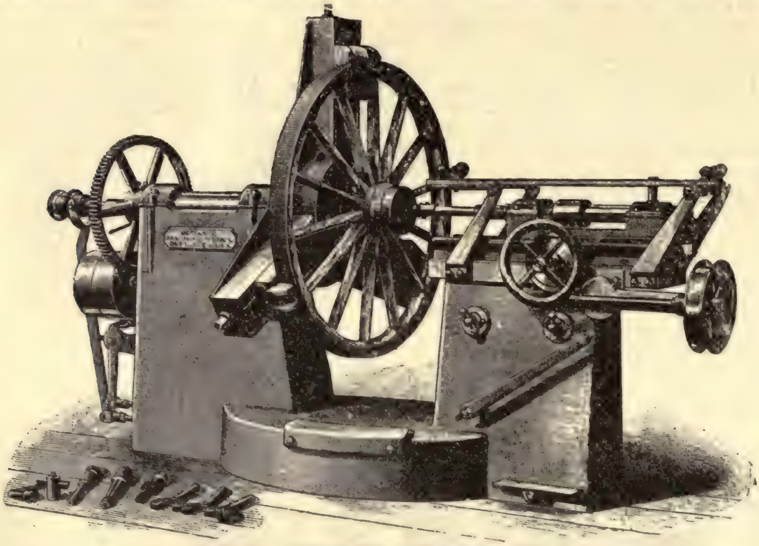


FIG. 7.—Automatic wheel-boxing machine.

by a treadle placed near the operator's stand at the front of the machine by the shifter bar controlling the chuck belt.

The Automatic Wheel-boxing Machine shown in Fig. 7 is for boring and finishing the hole in a wagon hub for receiving the boxes, doing this at one cut to any regular or irregular shape, relieving the center of the hub around the spokes, and cupping both ends of the hub to any desired shape. All these operations are done at one starting and stopping. There is a universal chuck fastened to a 6-in. spindle, all three of the dogs of which are actuated at once by turning with a wrench any one of the three screw threads, the range being for wheels from 20 to 60 in. diameter. There is a boring bar, having lengthwise and crosswise adjustment, for boring holes of any taper, size, or contour desired; and it has auxiliary cutter-heads to "depth" the backs of the hubs to accommodate the axle shoulder. After completing the cut the feed is disengaged automatically. The boring cutter consists of three independent cutters of square tool steel.

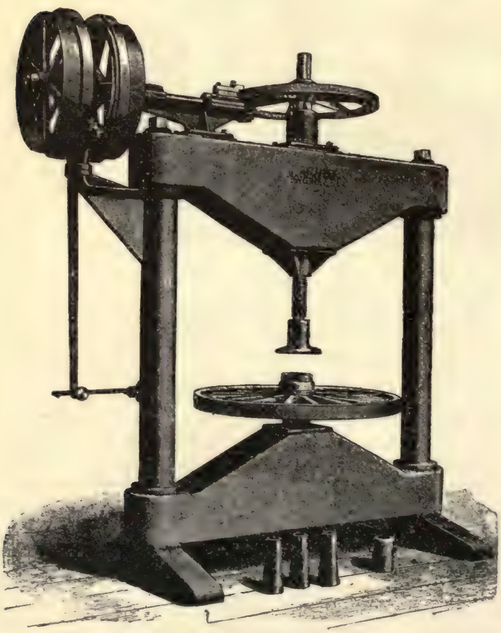


FIG. 8.—Power wheel press.

A Power Wheel Press is shown in Fig. 8, for pressing axle boxes into wheel hubs and pressing bands and flanges thereon; taking the place of the hydraulic presses often used for the same purpose. The screw has an up-and-down movement of 24 in., and the machine will take in a 60-in. wheel, upon which it will exert a pressure of 60,000 lbs. The direction of motion of the screw is regulated by the position of the hand lever which operates the friction clutch.

A hydrostatic power wheel press made by the Bentel & Margedant Co. has a vertical column, containing the cylinder, and supplied with crude petroleum under pressure from two vertical pumps, operated by eccentrics upon a shaft driven by a sprocket chain. A lever in front of the machine permits the oil to flow from a pressure reservoir to the rim cylinder, and the same lever releases the pressure and permits the oil to flow back to the suction side of the pumps. A pop valve permits escape of the liquid when the pressure in the ram reaches 80 tons. The ram rises $\frac{1}{6}$ in. for every rotation of the pump-driving eccentric haft.

WINDLASS, STEAM CAPSTAN. Fig. 1 represents a new form of steam capstan windlass, manufactured by the American Ship Windlass Co., of Providence, R. I., which has become almost exclusively adopted on American vessels. Among the novel features are the following: The valves of the engines are driven by a straight eccentric, without rocker

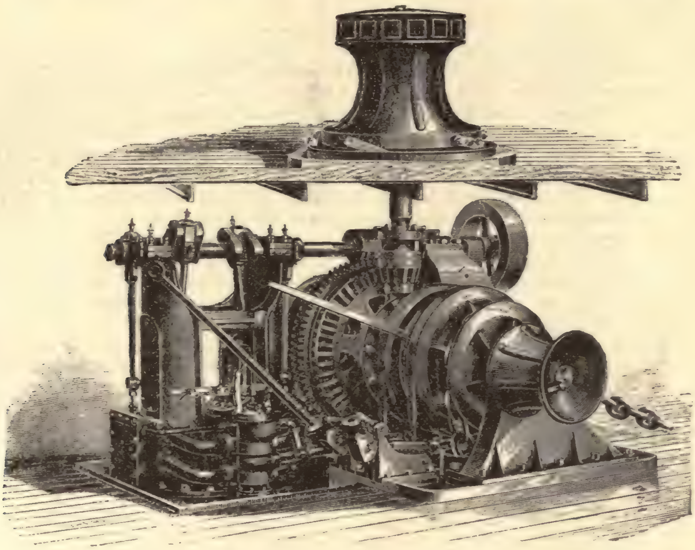


Fig. 1.—Steam capstan windlass.

shafts. There is a steam reverse valve for reversing the windlass in case of jamming of the ropes. The solid center bearing of the main shaft is arranged close to the gearing, so as to prevent any springing of the shaft under sudden strain. It will also be observed that the power is transmitted directly from engine to windlass, with no intermediate gearing. Engine and windlass are connected to one plate, by which the parts are tied together so that they can not get out of line. If the deck above twists or strains, or even is entirely swept away, the windlass can still be efficiently operated by steam. A novel lubricating contrivance, which constantly applies oil to the teeth of the worm gear, and a crank-shaft counterbalance, which balances the weight of the cranks, pistons, and rods, and prevents jerking motion, are added. The general construction is simple, strong, and effective. A detailed account of the mechanism will be found in the United States patents for the device, granted July 31, 1888, and March 14 and July 2, 1889.

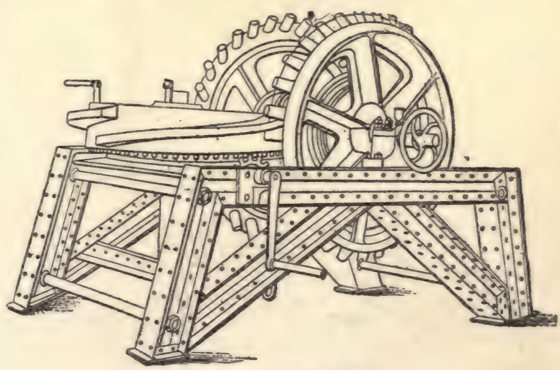


Fig. 2.—Ravelli windlass.

The Ravelli Windlass, Fig. 2, consists simply of a strong iron frame, of a bevel gearing, whose pinion is keyed to the winch shaft, and of a pair of helicoidal gearings. Upon the shaft that connects the two bevel wheels is keyed a drum, provided with depressions for the reception of the chain to which the load to be lifted is attached. The endless screw has several threads, but the latter do not, as usual, run around the entire circumference. If there are four threads, each of them covers but a quarter, and if there are six, each embraces but a sixth of the surface.

Upon the whole, this endless screw constitutes a sort of a disk, upon the circumference of which are arranged a variable number of pins that are slightly inclined with respect to the bases of the disk. At every fraction of a revolution corresponding to the number of the pins, one of them abandons the tooth of the gearing while the following pin and tooth engage. In order to diminish passive resistances, the teeth do not rub against the inclined planes formed by the pins, but roll over them. To this effect, they consist of truncated cone spindles loose upon journals set firmly into the felly of the gearing. The wear of these spindles is slow, because they are numerous and engage at relatively wide intervals of time. The power of this machine is very great, although no recourse is had to a differential mechanism nor to tackle. Stoppage is secured under full load, either in the raising or lowering of weights, without the intervention of any stop-work or brake. No flying back of the winch is to be feared, and this gives every security to the workman.

Wire Belting : see Belts.

Wire-cord Quarrying : see Quarrying Machines.

Wire Rope : see Rope-making Machines.

WIRE STRAIGHTENING. The ordinary method of straightening wire is by means of rolls, between which the wire is drawn, and which are adjusted by means of thumb-screws to bear heavily upon the bends. Another device is known as a rotary straightener, in which there are three pairs of dies, the middle pair being set out of line with the end pairs. The wire is carried through the dies, and the dies themselves are rotated, producing a jerking motion, the effect of which is to straighten out kinks, etc. A variety of automatic machines for wire straightening is described in a previous volume of this work, and these have not undergone any very material changes of late years.

An entirely new method of wire straightening, however, has been invented by Mr. John Wool Griswold, of Troy, N. Y., in which the use of machinery is entirely dispensed with. The wire, as it comes from the draw bench, is placed upon any suitable rotary support, and then led through an annealing furnace of any suitable construction. Here it is exposed to the air, for a considerable interval of space, until it finally reaches a pair of moving rolls, through which it passes. The rolls draw the wire from the reel and through the furnace, delivering it upon a table, where it is cut into lengths by a descending knife. During the passage of the wire through the furnace, and also through the air space, it is kept under tension by the action of the roll ; and in this way it is made straight. As the wire is finally cut into lengths, no coiling is necessary. This process has been found exceedingly effective, especially in the manufacture of wire into bale bands at the factory of Messrs. Griswold Bros., in Troy, N. Y.

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THE END.